BOEING VERTOL CO PHILADELPHIA PA F/6 1/3
INTERACTIONAL AERODYNAMICS OF THE SINGLE ROTOR HELICOPTER CONFI--ETC(U) AD-A061 767 DAAJ02-77-C-0020 USARTL-TR-78-23C-VOL-3B NL SEP 78 P F SHERIDAN UNCLASSIFIED 1 OF 3 AD61767

## USARTL-TR-78-23C



#### INTERACTIONAL AERODYNAMICS OF THE SINGLE ROTOR HELICOPTER CONFIGURATION

VOLUME IIIB - Flow Angle and Velocity Wake Profiles in Low Frequency Band, Air Ejector Systems and Other **Devices** 

Philip F. Sheridan

**▶** Boeing Vertol Company

P.O. Box 16858

CO Philadelphia, Pa. 19142

September 1978

Final Report for Period March 1977 - February 1978

Approved for public release; distribution unlimited.

Prepared for

HILE COPY

APPLIED TECHNOLOGY LABORATORY U. S. ARMY RESEARCH AND TECHNOLOGY LABORATORIES (AVRADCOM) Fort Eustis, Va. 23604

#### APPLIED TECHNOLOGY LABORATORY POSITION STATEMENT

In 1975 a wind tunnel test program was conducted in the Boeing-Vertol 20-foot V/STOL Wind Tunnel on a 1/5th-scale UTTAS model to investigate and find solutions for several aerodynamic problems encountered during the UTTAS flight-testing. Specifically, these tests focused upon (a) the structure of the hub/rotor wake in the vicinity of the empennage, (b) the formulation of the ground vortex and its relation to hub loads and fuselage loads during transition, and (c) the occurrence of vibratory air pressures from the blade passing over the fuselage. Only portions of the above-mentioned wind tunnel test data were reduced and analyzed in addressing the flight-test problems of the UTTAS aircraft.

Under Contract DAAJ02-77-C-0020, Boeing-Vertol completed analyses on the data to understand more completely the aerodynamic interactions that are involved and to formulate instructions for the guidance of designers in these respects. The results of these studies are applicable to all existing and future single-rotor/tail rotor helicopters. The data have been segregated according to aerodynamic interactions and associated phenomena/problem areas, From this body of knowledge, a generalized set of design guidelines meaningful to the single-rotor helicopter design concept formulation were developed and are included in these reports.

Mr. Robert P. Smith of the Aeronautical Technology Division, Aeromechanics Technical Area, served as project engineer for this effort.

#### DISCLAIMERS

The findings in this report are not to be construed as an official Department of the Army position unless so designated by other authorized documents.

When Government drawings, specifications, or other data are used for any purpose other than in connection with a definitely related Government procurement operation, the United States Government thereby incurs no responsibility nor any obligation whatsoever; and the fact that the Government may have formulated, furnished, or in any way supplied the said drawings, specifications, or other data is not to be regarded by implication or otherwise as in any manner licensing the holder or any other person or corporation, or conveying any rights or permission, to manufacture, use, or sell any patented invention that may in any way be related thereto.

Trade names cited in this report do not constitute an official endorsement or approval of the use of such commercial hardware or software.

#### **DISPOSITION INSTRUCTIONS**

Destroy this report when no longer needed. Do not return it to the originator.

Unclassified	
CURITY CLASSIFICATION OF THIS PAGE (When Data Entered)	
( Q ) (REPORT DOCUMENTATION PAGE	READ INSTRUCTIONS BEFORE COMPLETING FORM
USARTUTR-78-23C - VALL - 3 P	O. 3. RECIPIENT'S CATALOG NUMBER
TITLE (and Substite) INTERACTIONAL AERODYNAMICS OF THE	Final Report
SINGLE ROTOR HELICOPTER CONFIGURATION,	15 Mar 1977 - 13 Feb 1978
Volume III, Flow Angle and Velocity Wake Profiles in Low Frequency Band, Sub-Volume B, Air Ejector	6. PERFORMING ORG. REPORT NUMBER
Systems and Other Devices.	8. CONTRACT OR GRANT NUMBER(a)
The state of the s	DAAJ02-77-C-0020
Philip F. Sheridan	manufacture manufacture of the same of the same of
Boeing Vertol Company  P.O. Box 16858	10. PROGRAMELEMENT, PROJECT, TASK AREA & MORK UNIT NUMBERS
P.O. Box 16858 Philadelphia, Pa. 19142	62209A 1L262209AH76 00 189 EK
11. CONTROLLING OFFICE NAME AND ADDRESS Applied Technology Laboratory, U.S. Army Research and	September 1978
Technology Laboratories (AVRADCOM)	19. NUMBER OF PAGES
Fort Eustis, Va. 23604  14. MONITORING AGENCY NAME & ADDRESS(If different from Controlling Office)	202 15. SECURITY CLASS. (of this report)
won to the action in the control of	
	Unclassified  15a. DECLASSIFICATION/DOWNGRADING SCHEDULE
	SCHEDULE
	rofiles in Low Frequency Band, Ai jector Systems and Other Devices.
<ol> <li>DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different in the state of the st</li></ol>	from Report)
18. SUPPLEMENTARY NOTES	
Volume III of an eight volume report.  Volume III is comprised of two sub-volumes (A thr	ough B)
9. KEY WORDS (Continue on reverse side if necessary and identify by block number	
Wake Configuration	Air ejector
Flow Empennage Interaction Powered Model	Fairings
Aerodynamic Interaction Hub Cap Flow Environment 1 one to	
20. ABSTRACT (Continue on reverse side if necessary and identify by block number	
This is the second of the two sub-volumes compris documents present profiles of the RMS values of t	ing Volume III. These
velocities in the $1\Omega$ to $2\Omega$ range. The format is	
and velocity or flow angle on the abscissa. Each	graph shows a comparison of
the baseline flow to the flow modified by some de	vice or condition. This sub-
volume covers air ejector systems, air ejectors and wings, fairings and miscellaneous devices.	nub caps in same configuration,
mings, rati ings and miscertaneous devices.	

DD 1 FORM 1473 EDITION OF 1 NOV 65 IS OBSOLETE Unclassified

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Date Entered)

#### **PREFACE**

The entire report describing the investigation of INTERACTIONAL AERODYNAMICS OF THE SINGLE-ROTOR HELICOPTER CONFIGURATION comprises eight numbered volumes bound as 33 separate documents. The complete list of these documents is as follows:

Volume I, Final Report

Volume II, Harmonic Analyses of Airframe Surface Pressure Data

- A Runs 7-14, Forward Section
- B Runs 7-14, Mid Section
- C Runs 7-14, Aft Section
- D Runs 15-22, Forward Section
- E Runs 15-22, Mid Section
- F Runs 15-22, Aft Section
- G Runs 23-33, Forward Section
- H Runs 23-33, Mid Section
- I Runs 23-33, Aft Section

Volume III, Flow Angle and Velocity Wake Profiles in Low-Frequency Band

This volume is

A – Basic Investigations and Hubcap Variations
 B – Air Ejector Systems and Other Devices

Volume IV, One-Third Octave Band Spectrograms of Wake Split-Film Data

- A Buildup to Baseline
- B Basic Configuration Wake Explorations
- C Solid Hubcaps
- D Open Hubcaps
- E Air Ejectors
- F Air Ejectors With Hubcaps; Wings
- G Fairings and Surface Devices

Volume V, Harmonic Analyses of Hub Wake

Volume VI, One-Third Octave Band Spectrograms of Wake Single Film Data

- A Buildup to Baseline
- B Basic Configuration Wake Exploration
- C Hubcaps and Air Ejectors

Volume VII, Frequency Analyses of Wake Split-Film Data

- A Buildup to Baseline
- B Basic Configuration Wake Explorations
- C Solid Hubcaps

Open Hubcaps D

E

Air Ejectors
Air Ejectors With Hubcaps; Wings F G

Fairings and Surface Devices

#### Volume VIII, Frequency Analyses of Wake Single Film Data

A Buildup to Baseline

B Basic Configuration Wake Exploration

Hubcaps and Air Ejectors

#### TABLE OF CONTENTS

	PAGE
INTRODUCTION	6
OUTLINE OF WAKE INVESTIGATIONS (TABLE 1)	7
LIST OF TEST RUNS (TABLE 2)	11
INDEX TO RAKE POSITIONS (TABLE 3)	18
RAKE ORIENTATION DIAGRAM (FIGURE 1)	24
HOT FILM RAKE LOCATIONS (FIGURE 2-6)	25
UTTAS 1/4.85 - SCALE MODEL GEOMETRY AND PRESSURE TRANSDUCER LOCATION (FIGURE 7)	30
WAKE VELOCITY AND FLOW ANGLE PROFILES	31

#### INTRODUCTION

Volume III presents profiles of the wake split film data appearing in Volume IV in the one-third octave band format. Specifically, bands 7, 8, 9 and 10 in the plots of Volume IV are averaged to produce a mean value typifying the  $1\Omega$  to  $2\Omega$  regime where structural frequencies are likely to occur.

Volume III presents graphs of these  $1\Omega$  to  $2\Omega$  mean values for the four wake parameters plotted versus measurement location. The profile for each run (configuration) is compared in this format to the baseline profile. The difference in the profiles displays the effectivity of the model configuration in reducing the flow angles and velocity components and, hence, gauges the success of each step in the investigations.

The graphs showing these profiles are arranged in the same order as the runs in the Outline of Wake Investigations (Table 1). Volume III-A includes the following categories from Table 1:

- Build-up to Baseline
- Basic Configuration
- Effect of Hub Caps

Volume III-B includes the following categories:

- Effect of Air Ejectors
- Air Ejectors with Open Hub Caps and Underbodies
- Effect of Wings and Miscellaneous

The Table I outline and other material is included for reference and as context to the work of each sub-volume. Table 2, the List of Test Runs, arranges the runs in numerical order and gives pertinent text parameters.

The Index of Rake Positions, Table 3, lists the hot film transducer rake positions in the model coordinate system for each run and its test points. The main feature of Table 3 is the indexing of the test point number to the model water line station and butt line as it varied from run to run. The table groups the runs as they shared the indexing correspondence of point with position. It is emphasized that the runs in a group do not necessarily all share the same number of test points but they do have same correspondence within their respective ranges of test points.

The orientation of the rake is shown pictorially in Figures 1 through 6 for the various test runs. Figure 7 presents a scaled drawing of the model with reference to the three-axis coodinate system.

TABLE 1			
OUTLINE OF WAKE IN	VESTIGATIONS		
Description	Configuration Code		Base- line
Build-up to Baseline			
1. Nacelles removed	K <sub>13</sub> +H <sub>1</sub> -N	149	150
2. Blades off, rotating hub	$K_{13}-M+H_{1\cdot 0}$	160	156
3. " , non-rotating hub	$K_{13}-M+H_{1.0}$	158	156
4. " " , hub off	K <sub>13</sub> -M-H <sub>1.0</sub>	159	156
Basic Configuration  1. Wake Explorations near Empennage  (a) 15" Long. + traverse at T/R C.L.  (b) 9" Vert. + " above T/R "  (c) 2" " " in vortex  (d) 8" " " (continue 112)  (e) 13" " behind stab.  (f) Lateral traverse, left stab.  (One T.P. only)  (g) Same continued  (h) Same continued (One T.P. only)  (i) Lateral traverse right stab.  (j) T/R effect on wake	K <sub>11</sub> " " " " " " " " " " " " " " " " " "	111 112 113 114 115 116 117 118 119 121	    115
2. Climb/Descent Studies  (a) Climb 900 FPM  (b) Descent 800 FPM	K <sub>1 1</sub>	135 136	
Effect Of Hub Caps			
1. Solid Caps on Canister			
(a) 7.6" diam. 2.17" ht. soft Pitch Arms (b) 7.6" diam. 2.17" ht. stiff	K <sub>11</sub> -H <sub>1.0</sub> +H <sub>1.2</sub> K <sub>13</sub> +H <sub>1.2</sub>	137 153	136 156
Pitch Arms (b) 7.6" diam. 2.45" ht. flt. test config.	K <sub>13</sub> +H <sub>1.2.1</sub> +I <sub>1</sub> +E <sub>1.0</sub>	207	188

TABLE 1 (CONTI	NUED)		
OUTLINE OF WAKE INVE	STIGATIONS		
Description	Configuration Code*	Run No.	Base- line
Effect of Hub Caps (Continued)			
2. Solid Caps Raised Above Canister			
(a) 7.6" diam. 2.45" ht. 70" depth, .55 gap	H <sub>1.2.2</sub> +I <sub>1</sub> +E <sub>1.0</sub>	208	188
(b) 10.0" diam. 3.25" ht. 1.55" depth, .50" gap	H <sub>1.8.1</sub> +I <sub>1</sub> +E <sub>1.0</sub>	189	188
(c) 10.0" diam. 4.125" ht. 2.05" depth, .875" gap	H <sub>1.8.2</sub> +I <sub>1</sub> +E <sub>1.0</sub>	190	188
(d) Repeat of 189	11 11 11	210	188
3. Open Caps Without Underbody			
(a) 10.0" diam. 1.25" gap,blades (b) " " gap, no blades	H <sub>1.0.1</sub> +E <sub>1.0</sub>	193 166	188/166 <b>158</b>
	H <sub>1.14.1</sub> +I <sub>1</sub> +E <sub>1.0</sub> H <sub>1.0.1</sub> -M	211 165	188 158
	H <sub>1.0.3</sub> +I <sub>1</sub> +E <sub>1.0</sub> H <sub>1.7.1</sub> -M	191 168 167	188 156/167 158
(h) " " 4.00" gap,blades	H <sub>1.7.2</sub>	169	156
4. Open Caps with Underbody			
(a) 7.6" diam. 1.25" gap (b) " " " " center	1	194 198 202	188 188 194
(d) 10.0" diam5" gap, no blades	H <sub>1.5.1</sub> -M	164	158
(e) " " 1.25" gap, no blades	H <sub>1.5.2</sub> -M	161	158
(f) " " 2.0" gap, no blades	H <sub>1.5.4</sub> -M	163	158
(g) " " 4.0" gap, no blades	H <sub>1.5.3</sub> -M	162	158
(h) " " 1.25" gap	H <sub>1.5.2</sub>	154	156/161
*Basic Code is Kl3.			

TABLE 1 (CON	rinued)		
OUTLINE OF WAKE IN	VESTIGATIONS		
Description	Configuration Code*	Run No.	Base- line
5. Miscellaneous Hub Covers			
(a) Hub fairing 16" diam. (b) Wham-O-Frisbee 10" diam. (c) Fab. glass Frisbee 16" diam.	H <sub>1.3</sub> H <sub>1.9.0</sub> +E <sub>1.2</sub> H <sub>1.9.1</sub> +E <sub>1.2</sub>	151 182 183	150 181 181
Effect of Air Ejectors			
1. Basic system no blowing 2. " " 40 psi 3. " " 150 psi 4. Wide chord shroud 40 psi 5. Wide " " 150 psi 6. W/C shroud w. lip 40 psi 7. Same Contoured Parallel 150 psi 8. Bifurcated duct 0 psi 9. " " 40 psi 10. " " 150 psi	H <sub>1</sub> .0+E <sub>1</sub> .0  H <sub>1</sub> .0+E <sub>2</sub> .5.1  H <sub>1</sub> .0+E <sub>3</sub> .5.2  H <sub>1</sub> .0+E <sub>3</sub> .5.4	173 174 175 176 184 187 203 204	156 156/172 156/173 156/174 156/173 156/174 156 156/203 156/203
Air Ejectors with Open Hub Caps with Underbodies			
1. 7.6" diam. 1.25" gap, 0 psi 2. " " " 20 psi 3. " " " 40 psi 4. " " " 150 psi 5. " " " 0 psi 6. " " " 40 psi 7. " " 150 psi 8. Same with center post 9. 10.0" diam. 2.0" gap wide ch'd. shroud (150 psi)	H <sub>1.11.1</sub> +I <sub>2</sub> +E <sub>4.0</sub> """ H <sub>1.11.2</sub> +I <sub>2</sub> +E <sub>4.6</sub>	196 197 198 199 200 201	188/173 188/174 188/194 188/196 188/196
Effect of Wings and Misc.			
1. Wings (a) Nacelle-mounted stub wing (b) Single slotted flapped wing (c) Dougle slotted flapped wing (d) Boom-mounted stub wing	H <sub>1.0</sub> +W <sub>1.0</sub> +E <sub>1.1</sub> H <sub>1.0</sub> +W <sub>3.0</sub> +E <sub>1.0</sub> H <sub>1.0</sub> +W <sub>2.0</sub> +E <sub>1.0</sub> H <sub>1.0</sub> +W <sub>4.0</sub>	178 180 179 186	181 181 181 156
*Basic Code is K13.			

#### TABLE 1 (CONTINUED) OUTLINE OF WAKE INVESTIGATIONS Configuration Run Base-Code\* Description line No. 2. Crown Fairings (a) Flat top behind shaft 140 138 $K_{11} + D_1$ 138 (b) Round top behind shaft 141 $K_{11} + D_2$ H1+D4 (c) Extended flat top fairing 170 156 (d) Flat top + 16" cap, 4" gap 171 170 H1.7.2+D4 (e) Forward fairing/nacelle fairing P1 . 0 152 156 3. Surface Devices (a) Vortex generators K11+VG2.1 139 138 (b) Guidevane between nacelles 142 138 $K_{11}+FV_{1}$ (c) Longitudinal strakes H1.5.3+S4 155 156 $K_{11}+X_1$ 138 (d) 14% porosity spoiler 143

\*Basic Code is Kl3 unless

noted otherwise.

_			~												
		TAII.	ROTOR	Off	=		-	=	=	=		=	uO	Off	=
		MR HT.	h/d	8	=	=	=	=		=	-	=	= :	=	
		MODEL	9	-2.0	=	=	=	=	=	=		=	=	-4.5	-2.0
		MODEL	9 5	0.9	=		-	=	-		=	=	=	0.9-	0.9
	AKE	DISK	rbg.	æ	=	•			=	"		=	=		u
	IS IE HUB W	RPM	MR/TR	1433/0		=		=					1433/ 4500		
E 2	TEST RUN NS OF TH	Varun	KNOTS	80	=	=		=	=	=		•	=		
TABLE 2	LIST OF TEST RUNS BASIC INVESTIGATIONS OF THE HUB WAKE	NOT#IGNOS/NOT##########		$K_{ m ll}/ m l5"$ Long, wake traverse at TR center line	" /9" Vert. wake traverse above TR center line	" /2" Vert traverse through MR vortex	" /8" Vert. traverse below TR center line	" /13" Vert. traverse behind stabilizer	" /Lateral traverse - left stabilizer	" /116 continued	" /116 continued	" /Lateral traverse - right stabilizer	K <sub>ll</sub> +T <sub>2</sub> /Effect of tail rotor flow on wake	$K_{11}/$ Wake in 900 fpm climb	" /Wake in 800 fpm descent
		RUN	NO.	111	112	113	114	115	116	117	118	119	121	135	136

# TABLE 2 (CONTINUED) LIST OF TEST RUNS EVALUATION OF WAKE-ALTERING DEVICES

RUN	CONFIGURATION/CONDITION	VTUN	RPM	DISK	MODEL	MODEL	MR HT.	TAIL
NO.		KNOTS	MR/TR	pst.	° 5	· A	h/d	ROTOR
137	K <sub>11</sub> -H <sub>1.0</sub> +H <sub>1.2</sub> /Effect of 7.6 inch diam, solid hub cap	80	1433/0	8	9	-3.8	8	Off
138	K <sub>11</sub> /Repeat of base run			=	=			:
139	Kll+VG2,1/Effect of vortex gener- ators on aft crown	=		=	=	=	=	=
140	$\mathrm{K_{11}^{+}D_{1}/Flat-topped}$ "doghouse" fairing on aft crown	=		=		•	=	:
141	$K_{11}^{+}D_{2}/Rounded$ -top fairing	=		=	=		•	:
142	K <sub>11</sub> +FV <sub>1</sub> /Deflection vane on crown between nacelles	=	=	=		=	=	=
143	$K_{11}^{+}X_{1}^{\prime}/\text{Variable porosity spoiler}$		=		-	=	•	:
149	$ ext{K}_{13}^{+H_1-N_1/\text{Effect of nacelles off also}}$ add stiff pitch arms $( ext{K}_{13})$	09	1075/0	4.5	:	•		
150	$K_{13}+H_{1}/60$ knot baseline	-	=	=	•	=	=	:
151	K <sub>13</sub> +H <sub>1.3</sub> /16 inch diam. helmet fair- ing	=	=	=	=	=	=	=
152	$K_{13}^{+}P_{1.0}/Pylon$ and intake fairings	80	1433/0	8	=			=
153	$\mathrm{K}_{13}{}^{+}\mathrm{H}_{1.2}/\mathrm{Repeat}$ 137 with $\mathrm{K}_{13}$ pitch arms		=	=	•		=	ı

		TAIL	ROTOR	Off	-	-	=		=	=		=	=	=	=
		MR HT.	h/d	8	=	=	=		=	=	-				
		MODEL	0 =	-3.8	=	=	=		=	=	=	=		=	=
		MODEL	o <sub>B</sub>	9		=	=	=	=	=	=	=			=
	ES	DISK	LDG.	8	=	=	=		=	=	-	-	=		=
) S	IG DEVIC	RPM	MR/TR	1433/0	=	-	0/0		1433/0	0/0	=		=	=	=
ONTINUED	-ALTERIN	VTUN	KNOTS	80	=	=	=	=	=	=		=	=		
TABLE 2 (CONTINUED) LIST OF TEST RUNS	EVALUATION OF WAKE-ALTERING DEVICES	CONFIGURATION/CONDITION		K13+H1.5.2/10" open hub cap, 7" underbody, 1.25"qap	0	K <sub>13</sub> +H <sub>1.0</sub> /Baseline with K <sub>13</sub> ,i.e., stiff pitch arms	K <sub>13</sub> -M+H <sub>1.0</sub> /Wake studies with blades off, hub not rotating	K <sub>13</sub> -M-H <sub>1.0</sub> /Wake studies with hub off	K <sub>13</sub> -M+H <sub>1.0</sub> /Same as 158 except hub is rotating	K <sub>13</sub> -M+H <sub>1.5.2</sub> /Repeat of 154 without blades	K <sub>13</sub> -M+H <sub>1.5.3</sub> /Same as 161 except 4"	K <sub>13</sub> -M+H <sub>1.5.4</sub> /Same as 161 except 2"	K <sub>13</sub> -M+H <sub>1.5.1</sub> /Same as 161 except 0.5" gap	K <sub>13</sub> -M+H <sub>1.0.1</sub> /10" open hub cap,no underbody,same cap vert.position as Run 154	K <sub>13</sub> -M+H <sub>1.0.2</sub> /Same as 165 with cap lowered by 0.5"
		RUN	NO.	154	155	156	158	159	160	161	162	163	164	165	166

	Ol C Blakt	TI III III III III III III III III III						
	LIST OF TEST RUNS EVALUATION OF WAKE-ALTERING DEVICES	TEST RUNALING	o) IS S DEVICE	Ø				
RUN	CONFIGURATION/CONDITION	VTUN	RPM	DISK	MODEL	MODEL	MR HT.	TAIL
NO.		KNOTS	MR/TR	LDG.	g	•	þ/q	ROTOR
167	K <sub>13</sub> -M+H <sub>1.7.1</sub> /16" open cap, no underbody, 2" gap	80	0/0	œ	9	-3.8	8	Off
168	1,	=	1433/0	=	=	=	=	=
169	K <sub>13</sub> +H <sub>1.7.2</sub> /16" open cap, no under- body, 4" gap	-	=	=	=	=	=	=
170		=	=	=	=	=	=	=
171	K <sub>13</sub> +H <sub>1.7.2</sub> +D <sub>4.0</sub> /Same fairing as 170, same cap as 169				=	-	=	
172	K13+H1.0+E1.0(Opsi)/Basic air ejector zero blowing baseline	=	=	=	=	=	=	=
173	$^{\mathrm{K}_{13}}^{+\mathrm{H}_{1.0}}^{+\mathrm{E}_{1.0}}$ (40 psi)/Same as 172 with 40 psi supply	=	=	=	=	=	=	=
174	K <sub>13</sub> +H <sub>1.0</sub> +E <sub>1.0</sub> (150 psi)/Same as 172 with 150 psi supply	=	=	=	=		=	=
175	r w			=	=		=	=
176	$K_{13}^{+H_{1.0}^{+E}}$ 2.5.1(150 psi)/Same as 174 with 150 psi supply	=	=	-	-		=	-
177	K <sub>13</sub> +H <sub>1</sub> .5 <sub>1</sub> 4+E <sub>2</sub> ,5,1(150 psi)/Same as 13 with 10" cap like 163	E	=	=	s	=	=	=
178	$^{K_{13}}$ $^{+H_{1.0}}$ $^{+W_{1.0}}$ $^{+E_{1.1}}$ $^{(0)}$ psi)/Nacelle mounted wing	=		=	•	=		=

TABLE 2 ( LIST OF  EVALUATION OF WAKE-  179 K13+H1.0+W2.0+E1.0 (0 psi)/Double  180 K13+H1.0+W2.0+E1.0 (0 psi)/Single  181 K13+H1.0+E1.2 (0 psi)/Baseline with  ejector tube moved aft  182 K13+H1.9.0+E1.2 (0 psi)/Standard 10"  frisbee  183 K13+H1.9.1+E1.2 (0 psi)/16" fabri-  cated frisbee  184 K13+H1.0+E3.5.2 (40 psi)/3me as  185 K13+H1.0+E3.5.2 (150 psi)/Same as  186 K13+H1.0+E3.5.2 (150 psi)/Same as  187 K13+H1.0+E3.5.4 (150 psi)/Like 185  with modified shroud  188 K13+H1.0+1+E1.0 (0 psi)/Baseline  with I1 instr. ring  189 K13+H1.0+11+E1.0 (0 psi)/Solid cap,  100 K13+H1.8.1+11+E1.0 (0 psi)/Same as
--

			TAIL		Off	:	=	=	=	=	2	=	=	=	=	=
			H	h/d	8	=	=	=	=	=	=	•	•	=	=	=
			MODEL	•	-3.8	:	=	=	=	=	2	=		=	=	=
			MOI	<b>9</b>	9		=	=	=	=	2	=	=	-	=	=
		w	DISK	LDG. P\$f	8		u.	=	=	=	2	=		=	=	=
(C	St	3 DEVICE	RPM	MR/TR	1433/0		н	а	=	u	u	=		=	=	=
CONTINUE	TEST RUN	ALTERIN	Vrun	KNOTS	80	=	=	=	=		и	=		=		=
TABLE 2 (CONTINUED)	LIST OF TEST RUNS	EVALUATION OF WAKE-ALTERING DEVICES	NOT#IGNOO/NOT# # ## HOO	NOTITION CONTINUE	Kl3+Hl.0.2+Il+El.0 (0 psi)/10" cap, no underbody, 1.87" gap	.0 (0 1	Kl3+Hl.ll.l+I2+El.0(0 psi)/7.6" cap, underbody, 1.25" gap	El.0( psi a	K13+H1.11.1+I2+E1.0(40 psi)/Same as 194 with 40 psi air	K13+H1.11.1+I2+E1.0(150 psi)/Same as 194 with 150 psi air	$^{\mathrm{K}_{13}+\mathrm{H}_{1}}$ .11.1 $^{+\mathrm{I}_{2}+\mathrm{E}_{4}}$ .0 (0 psi)/Same as 194 except blowing tube 2" aft	K13+H1.11.1+I2+E4.0 (40 psi)/Same as 198 with 40 psi air	K13+H1,11,1+I2+E4.0 (150 psi)/Same as 198 with 150 psi air	Kl3+Hl.11.2+I2+E4.0 (150 psi)/Same as 200 except center support cap	2+12/Baseline with I2	K <sub>13</sub> +H <sub>1.0</sub> +E <sub>5.0</sub> (0 psi)/Bifurcated air duct baseline
			RUN	NO.	191	193	194		196	197	198	199	200	201	202	203

(O	NS G DEVICES	RPM DISK ANGLES HT. TAIL	Psf a° w h/d	1433/0 8 6 -3.8 ~ Off		= = =	=	= = =	=======================================			
TABLE 2 (CONTINUED)	LIST OF TEST RUNS EVALUATION OF WAKE-ALTERING DEVICES	CONFIGURATION/CONDITION		K13+H1.0+E5.0 (150 psi)/Bifurcated duct with 150 psi air	K <sub>13</sub> +H <sub>1.0</sub> +E <sub>5.0</sub> (40 psi)/Same as 204 with 40 psi air	K <sub>13</sub> +H <sub>1.2.1</sub> +I <sub>1</sub> +E <sub>1.0</sub> (0 psi)/7.6" solid cap, no gap	K <sub>13</sub> +H <sub>1.2.2</sub> +I <sub>1</sub> +E <sub>1.0</sub> (0 psi)/Same as 207 except 0.55" gap	K <sub>13</sub> +H <sub>1.15.1</sub> +I <sub>1</sub> +E <sub>1.0</sub> (0 psi)/Repeat of 189	K <sub>13</sub> +H <sub>1.14.1</sub> +I <sub>1</sub> +E <sub>1.0</sub> (0 psi)/Like 189 and 210 except cap is oper			
		RUN	ON	204	205	207	208	210	211			

TABLE 3 INDEX TO RAKE POSITIONS RUN LOCATION TEST WATER BUTT MODEL NUMBER FIGURE POINT LINE STATION LINE 111 -7:25 20 53.5 1 103.1 21 22 105.0 \*\* 24 107.0 26 \* 109.0 28 111.0 112.9 30 32 114.9 34 116.9 36 118.9 -7.25 112 48.9 1 2 107.3 4 50.8 6 52.7 103.3 8 54.5 \*\* 56.2 10 12 57.2 113 2 51.7 103.3 -3.25 1 4 52.3 6 52.8 8 53.3 10 53.9 11 53.3 -3.25 114 44.5 103.0 1 46.4 4 6 48.2 11 8 50.0 10 51.9 115 52.9 124.7 -3.25 1 3 52.0 4 50.0 6 9 48.0 10 46.0 44.1 12 14 42.1 53.0 16 54.0 18 55.0 20

	TABLE 3	CONTINUED	))	
IN	DEX TO RAI	KE POSITIO	ONS	
TEST POINT	WATER LINE	MODEL STATION	BUTT LINE	LOCATION FIGURE
7	36.9	100.5	-17.5	1
2 4 6 8 10	37.6 37.3	100.5 99.6	-16.0 -14.0 -12.0 -10.0 - 8.0	1
2	37.6	100.5	- 6.0	1
2 5 8 9 14 16 20 25	37.3 " " " 51.5 52.3	99.6 " " 102.5 101.7	+ 6.0 8 10 14 16 17.5 -17.5	1
3	62.9	129.0	+ 5 7	2

117	2 4 6 8 10	37.6 "37.3	100.5 99.6	-16.0 -14.0 -12.0 -10.0 - 8.0	1
118	2	37.6	100.5	- 6.0	1
119	2 5 8 9 14 16 20 25	37.3 "" "" 51.5 52.3	99.6 " " 102.5 101.7	+ 6.0 8 10 14 16 17.5 -17.5	1
121	3 4 6 8 10	62.9 53.5 50.1 46.0 42.1	129.0	+ 5.7	2
135	2 4 6 8 10 12 14	56.9 54.5 52.5 50.5 48.5 46.5 44.5	106.3	- 5.7 "	3
136	2 4 6 8 10 12 14 17 18	56.5 54.5 52.5 50.6 48.5 46.5 44.5 37.1 39.0 41.0	104.0	- 8.0	4
10					

RUN NUMBER

### TABLE 3 (CONTINUED) INDEX TO RAKE POSITIONS

RUN NUMBER	TEST POINT	WATER LINE	MODEL	BUTT	LOCATION FIGURE
137	3 5 7 9 11 13 15 17	38.7 39.9 42.0 44.0 46.0 48.0 50.0 52.0 54.0	98.4 100.5 103.6	- 8.0 "" "" ""	5
138-41, 143	2 3 4 5 6 7 8 9	38.8 40.0 42.0 44.0 46.0 48.0 50.0 52.0 54.0	98.4 100.5 103.6	- 8.0	5
142	7 8 9 10 11 12 13 14 15 16	37.8 40.2 42.0 44.0 46.0 48.0 50.0 52.0 54.0 56.8	98.4 " 100.5 103.6	- 8.0 "	5

TABLE 3 (CONTINUED)

INDEX TO RAKE POSITIONS

RUN NUMBER	TEST POINT	WATER LINE	MODEL STATION	BUTT	LOCATION FIGURE
149-151	2 3 4 5 6 7 8 9	38.8 40.0 42.0 44.0 46.0 48.0 50.0 52.0 54.0	98.5 100.6 103.5	- 8.0	5
152-6, 158 161-4, 166 167, 169-71 175, 177-9 180,182,184 186-8, 190 191,193,194 196,198,201 204,207,208	5 6 7 8 9	42.9 44.9 46.9 48.9 50.9 52.9 54.9 56.9	97.9 100.6 104.6	0.0	6
159	1 2 3 4 5	54.9 52.9 50.7 48.6 46.7	104.6	0.0	6
160,203	5 6 7 8 9 10	42.9 44.9 46.9 48.9 50.9 52.9 54.9	97.9 100.6 104.6	0.0	6
165	3 4 5 6 7 8	44.9 42.9 46.9 48.9 50.9 52.9	97.9 100.6 104.6	0.0	6

TABLE 3 (CONTINUED)

INDEX TO RAKE POSITIONS

RUN NUMBER	TEST POINT	WATER LINE	MODEL STATION	BUTT LINE	LOCATION FIGURE
168, 183	4 5 6 7 8 9 10	42.9 44.9 46.9 48.9 50.9 52.9 54.9	97.9 100.6 104.6	0.0 " " "	6
172	3 4 6 7 8 9 10	42.9 44.9 44.9 46.9 48.9 50.9 52.9 54.9	97.9 " 100.6 104.6	0.0	6
173,174,176 185,195,197 199,200,205 210	2	42.9 44.9 46.9 48.9 50.9 52.9 54.9	97.9 100.6 104.6	0.0	6
181	2 3 4 5 6 7 9 10 11 12 13	42.9 44.9 46.9 48.9 50.9 52.9 54.9	97.9 100.6 104.6 "	0.0	6

#### TABLE 3 (CONTINUED) INDEX TO RAKE POSITIONS RUN TEST WATER MODEL BUTT LOCATION NUMBER POINT LINE STATION LINE FIGURE 189 29 42.9 97.9 0.0 6 30 44.9 31 II 46.9 100.6 32 11 48.9 33 " 34 50.9 11 104.6 35 \*\* 36 48.9 11 100.6 37 \*\* 50.9 104.6 38 52.9 39 54.9 11 202 3 43.4 97.9 0.0 6 4 44.9 5 46.9 \*\* 100.6 6 48.9 50.9 104.6

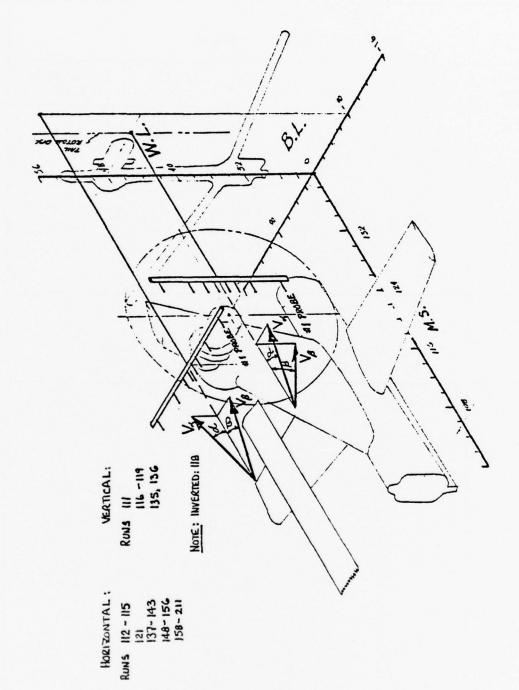


FIGURE 1 - RAKE ORIENTATION DIAGRAM

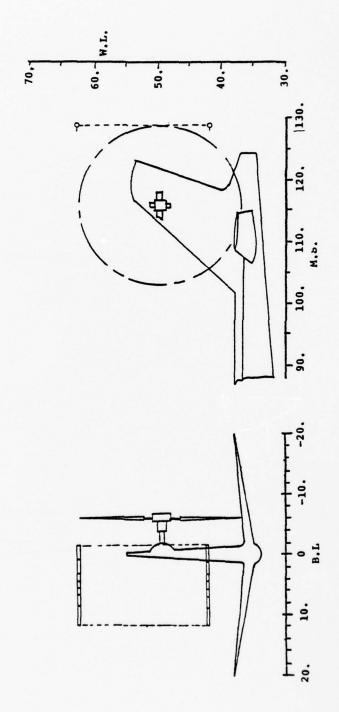


FIGURE 2 -HOT FILM RAKE LOCATIONS



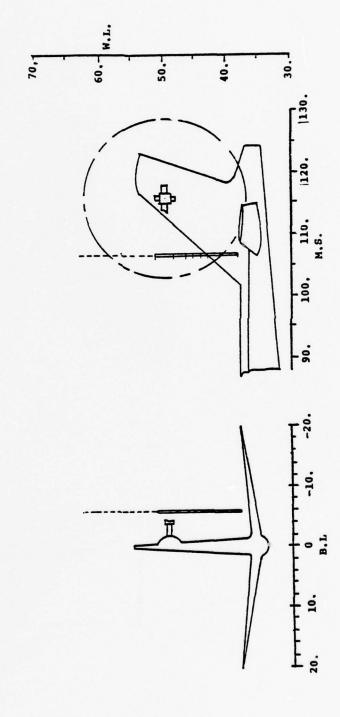


FIGURE 3 -HOT FILM RAKE LOCATIONS



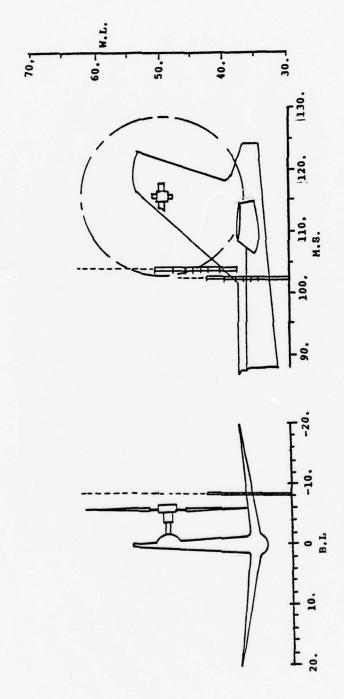


FIGURE 4 -HOT FILM RAKE LOCATIONS

RUN 137, 138, 139, 140, 141, 142, 143, 148, 149, 150, 151

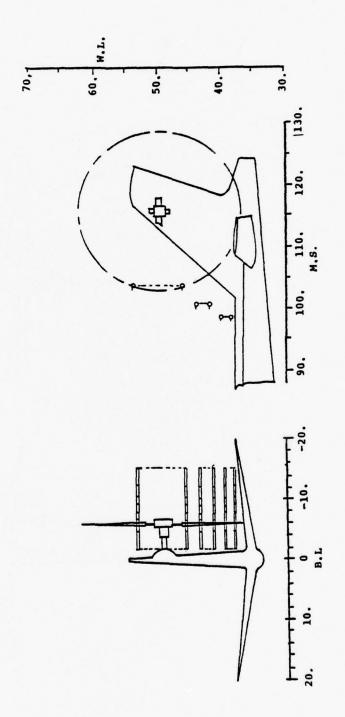


FIGURE 5 -HOT FILM RAKE LOCATIONS

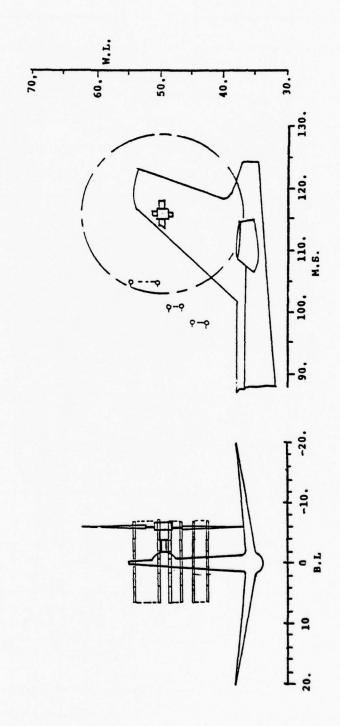
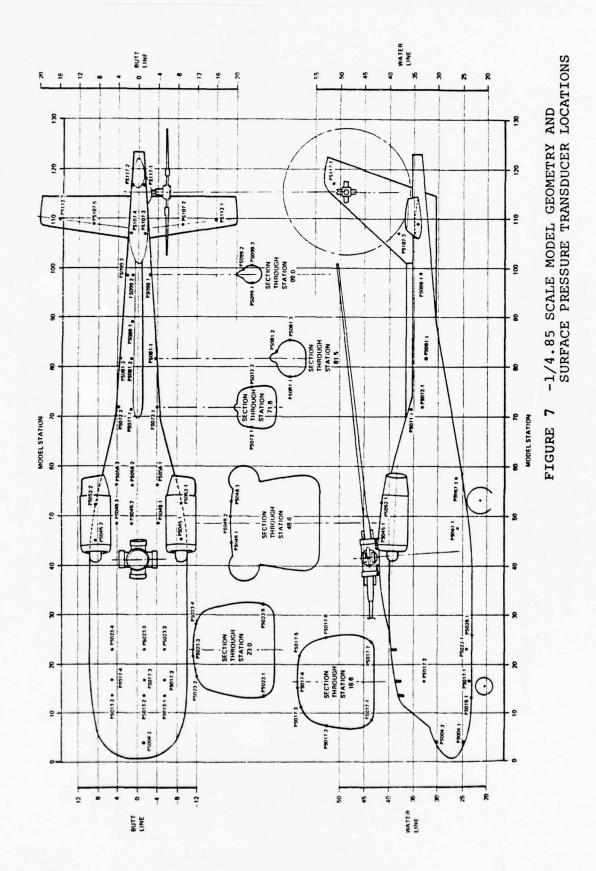
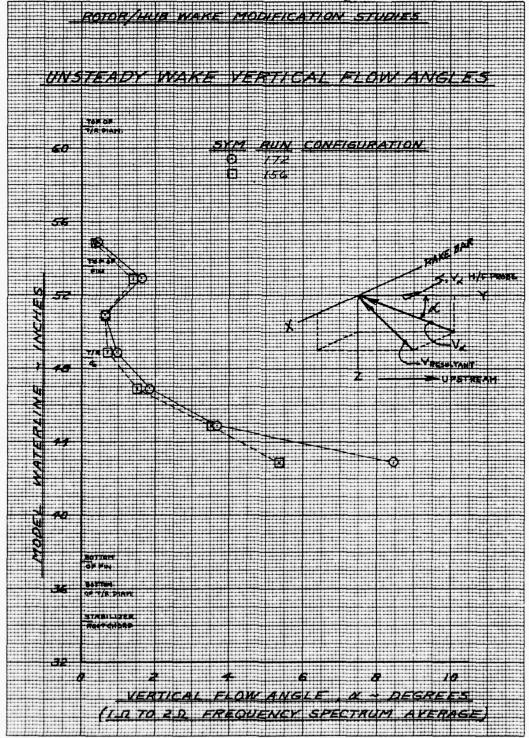
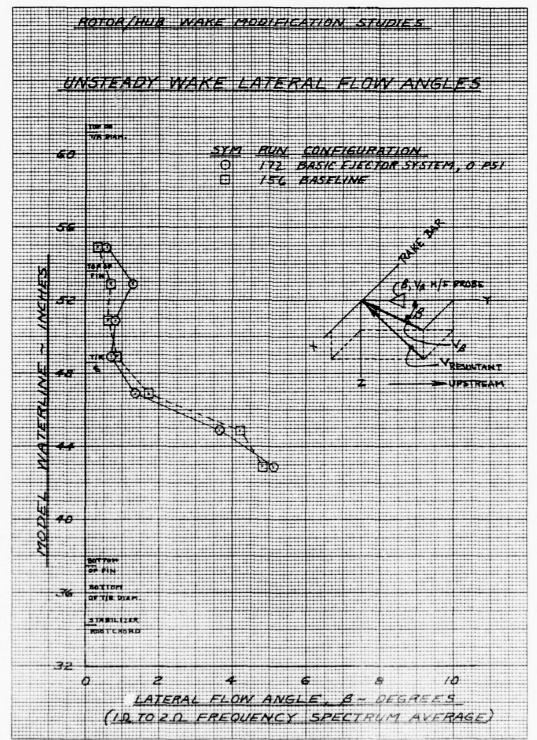
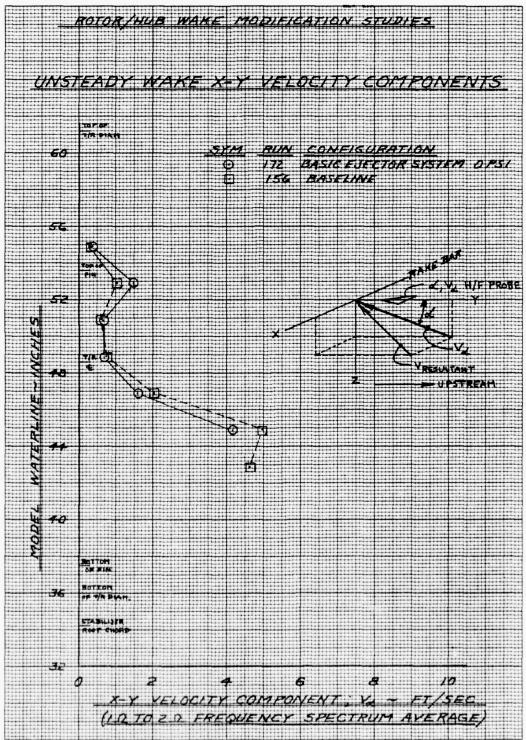


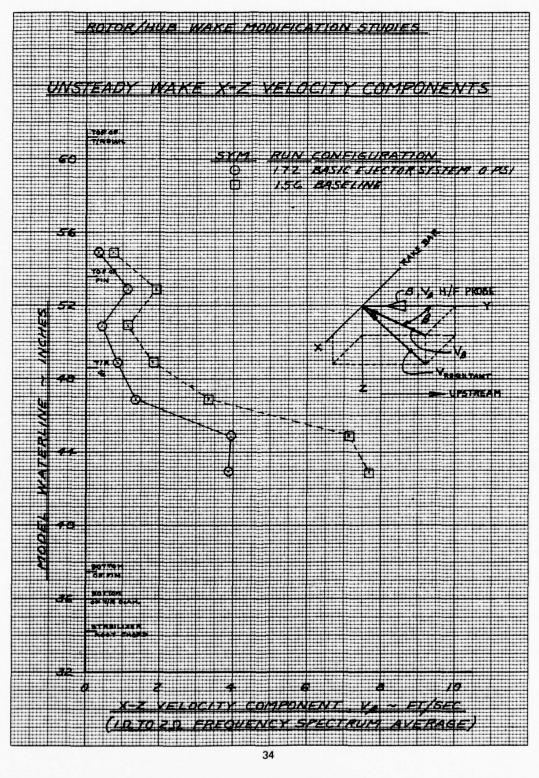
FIGURE 6 -HOT FILM RAKE LOCATIONS

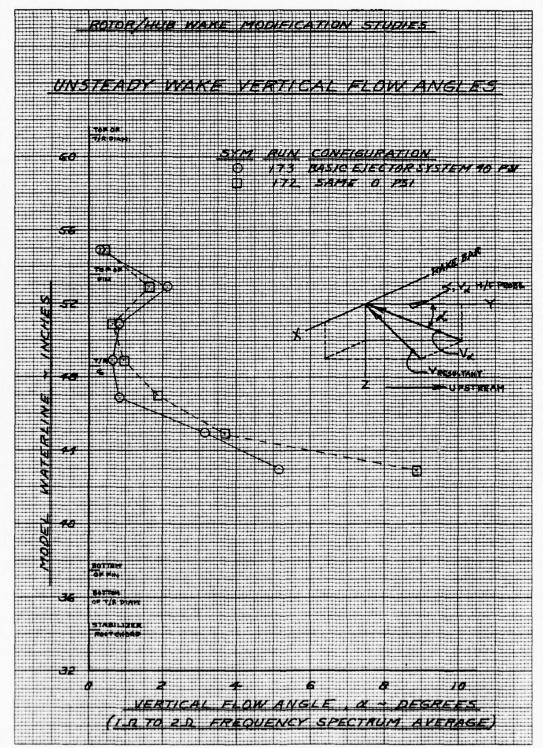


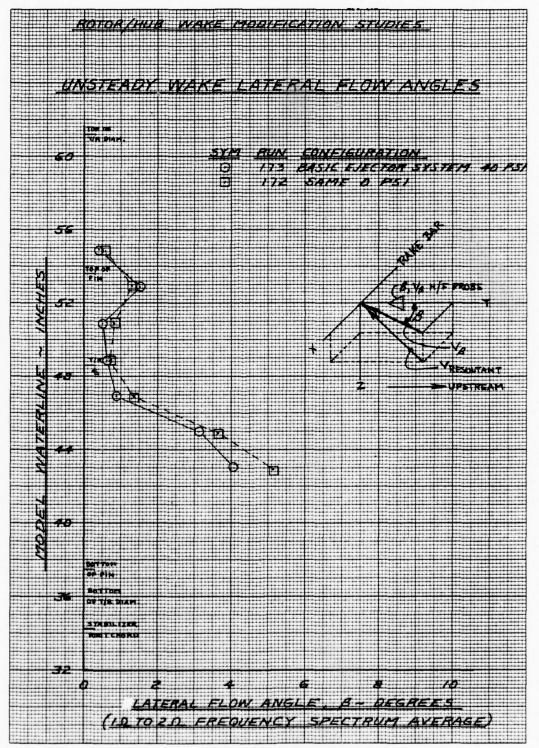


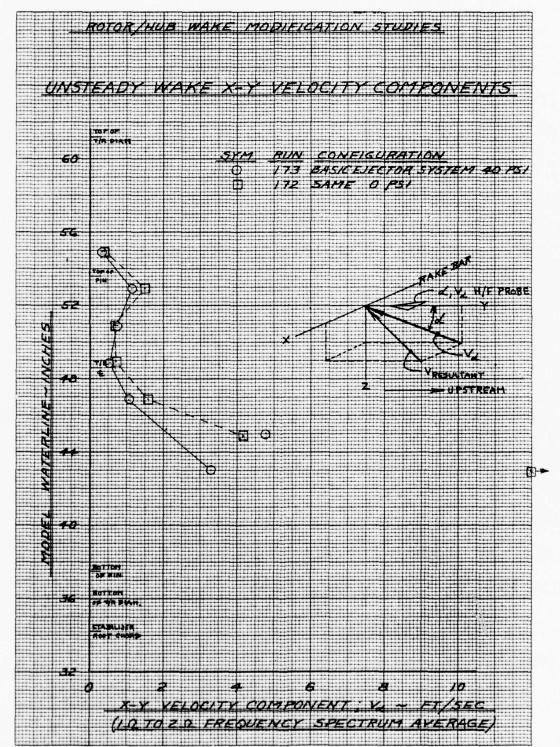


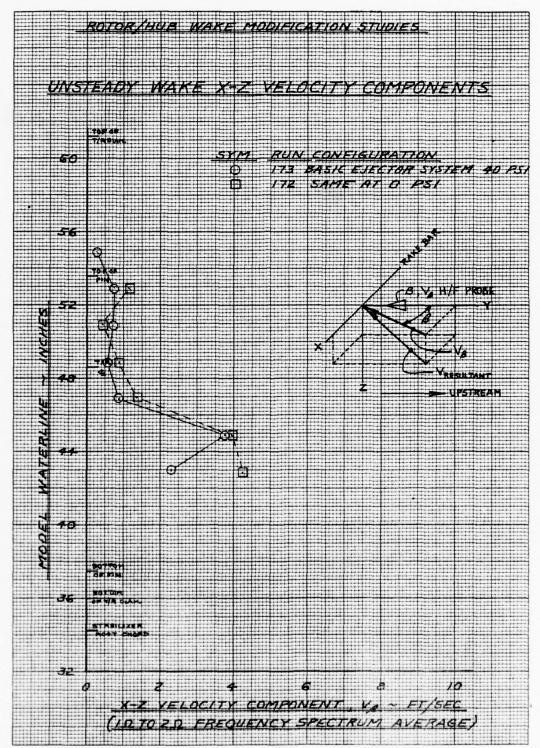


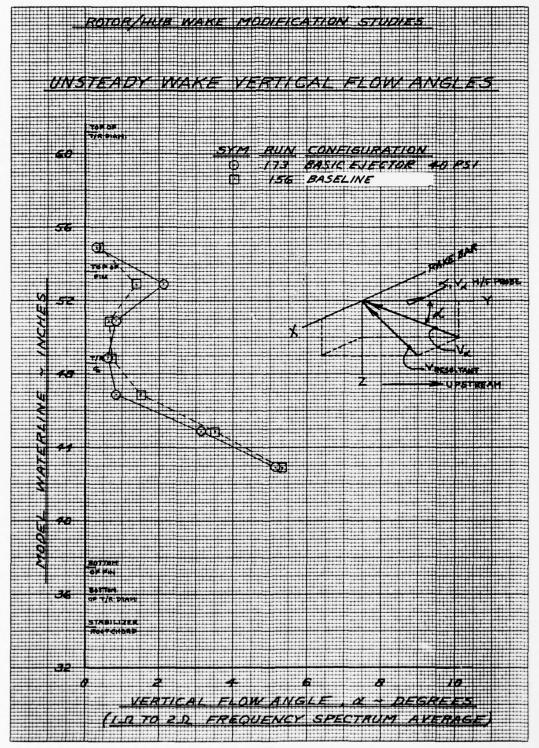


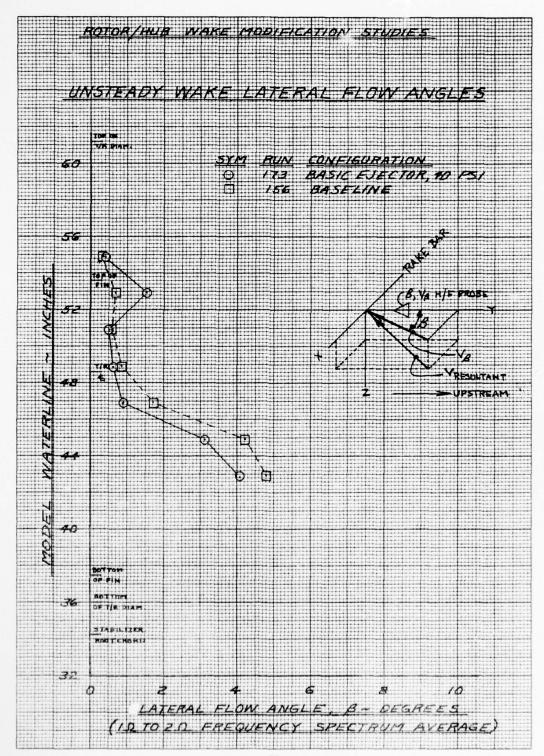


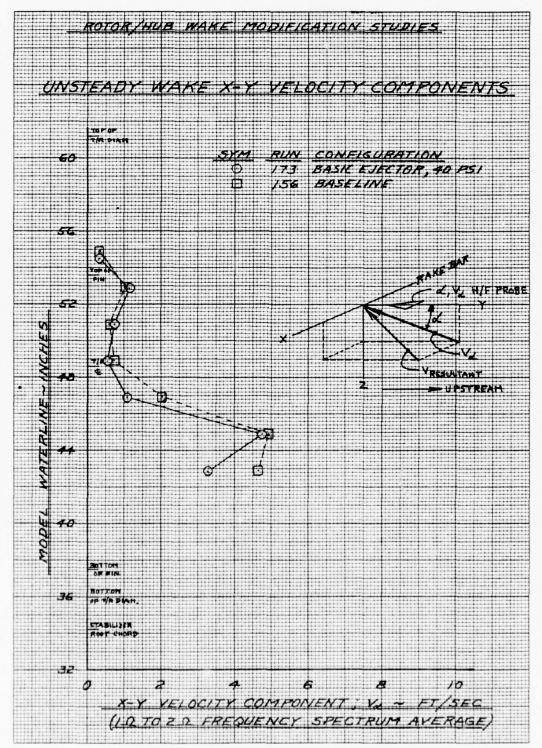


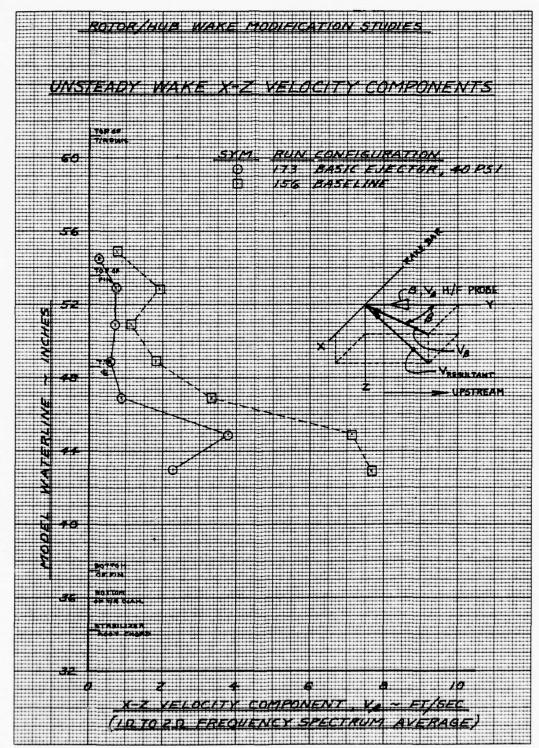


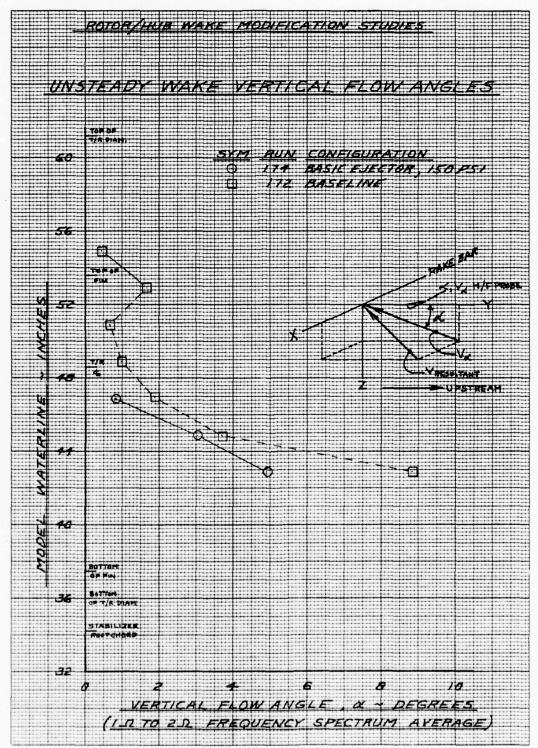


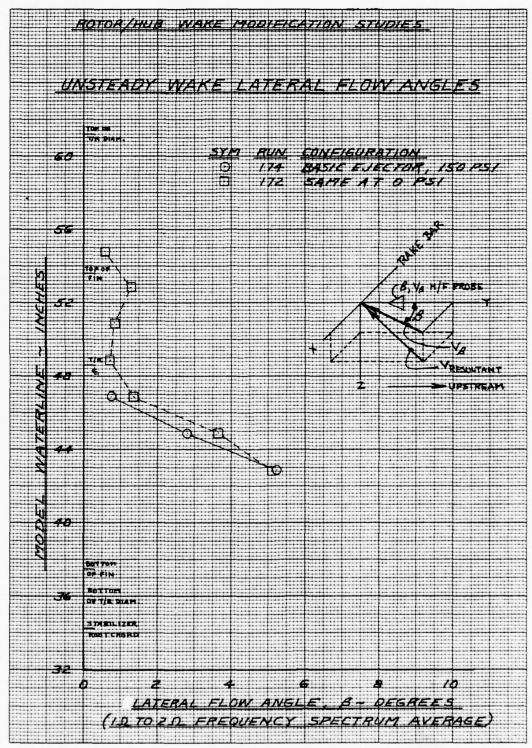


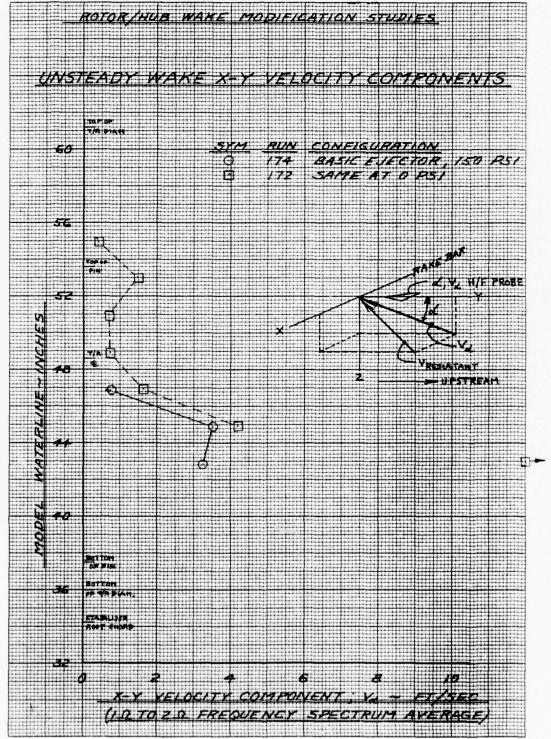


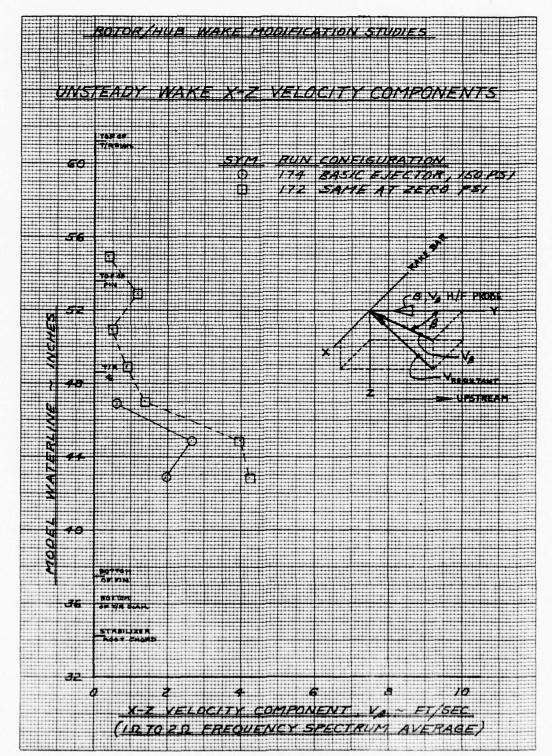


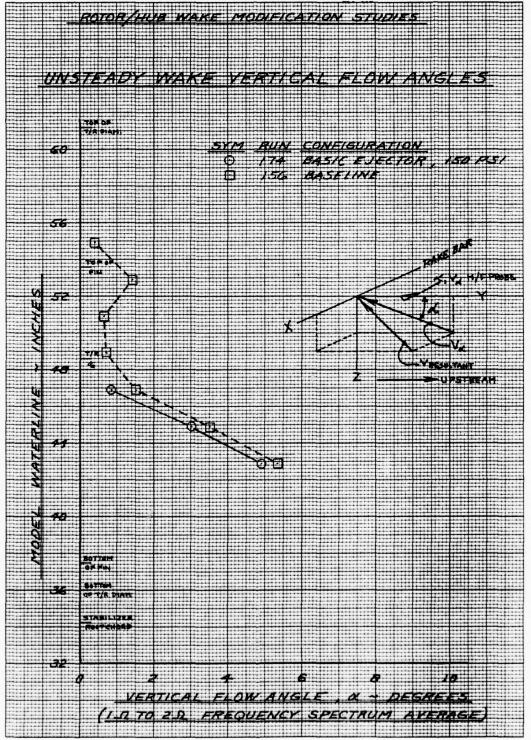


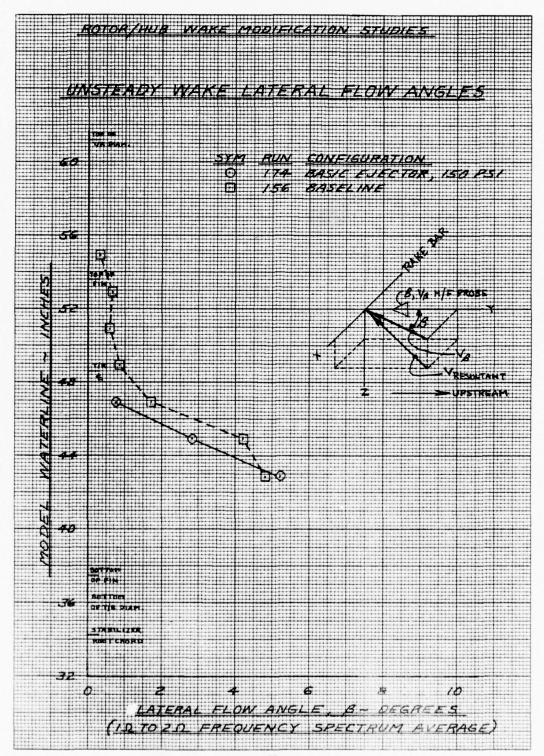


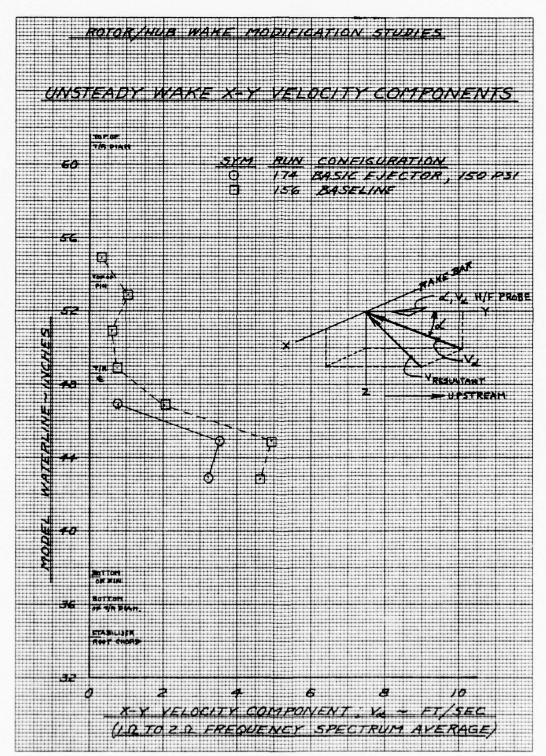


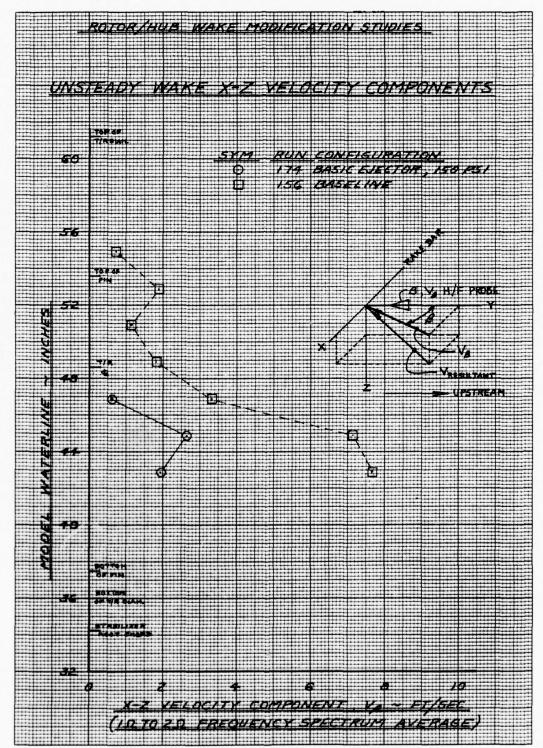


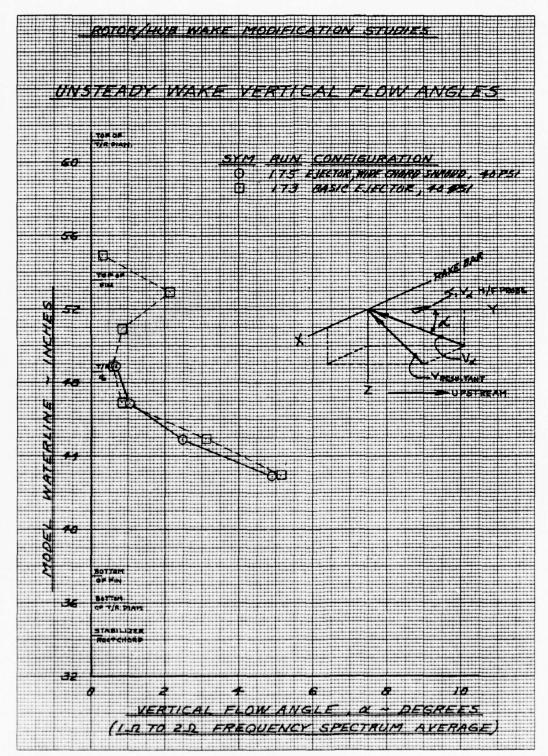


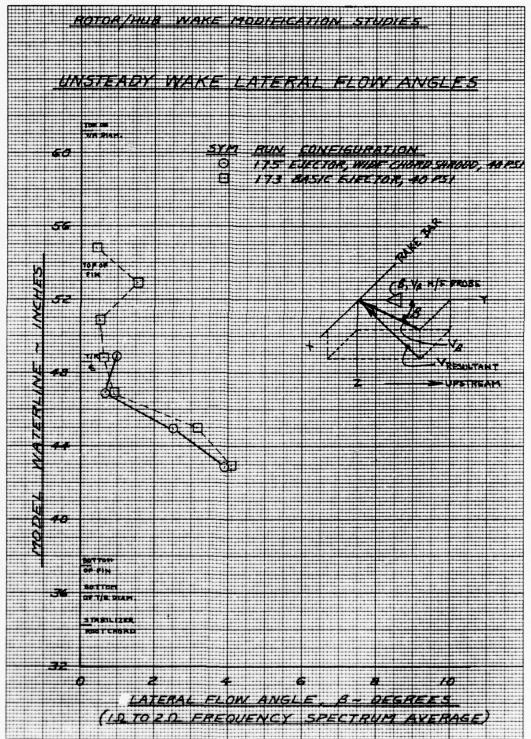


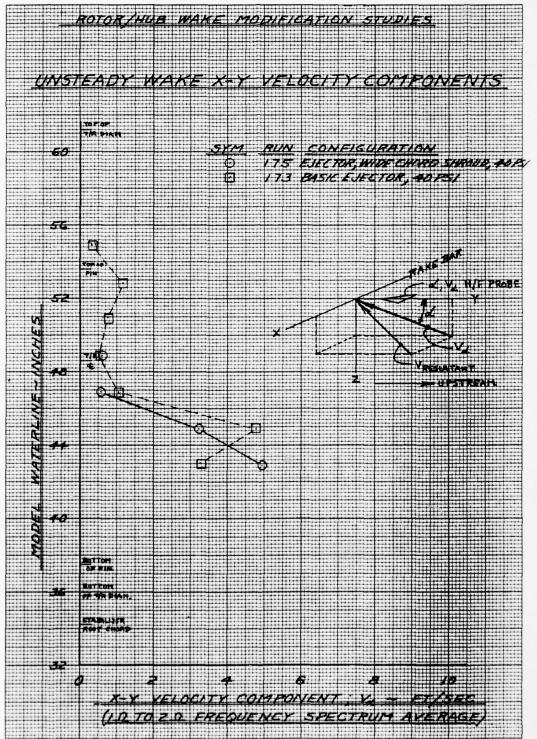


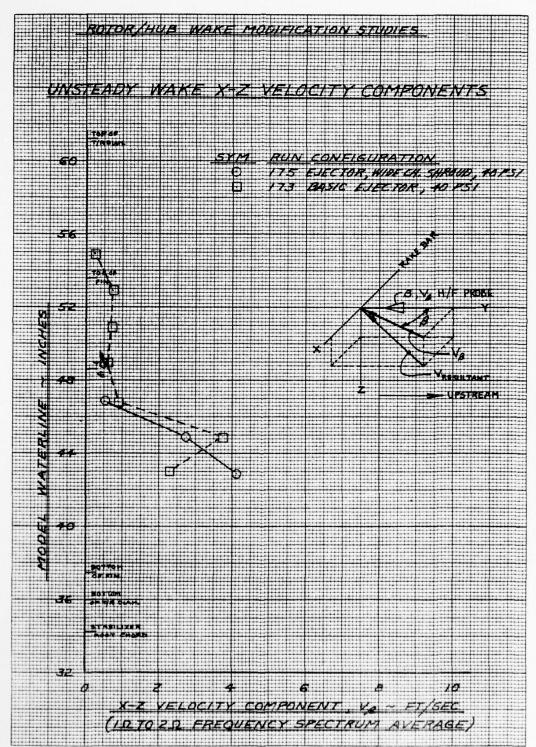


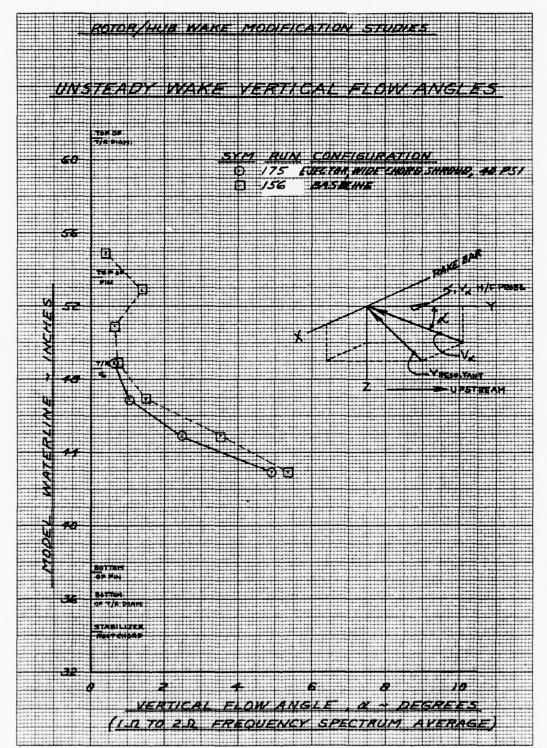


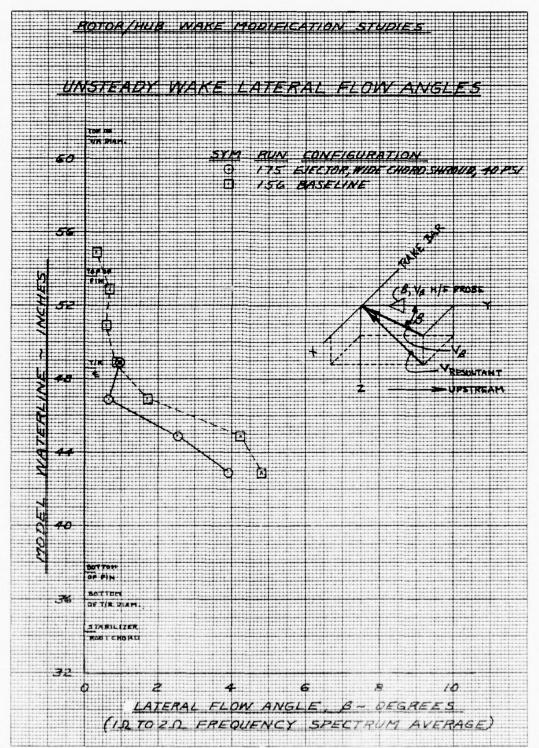


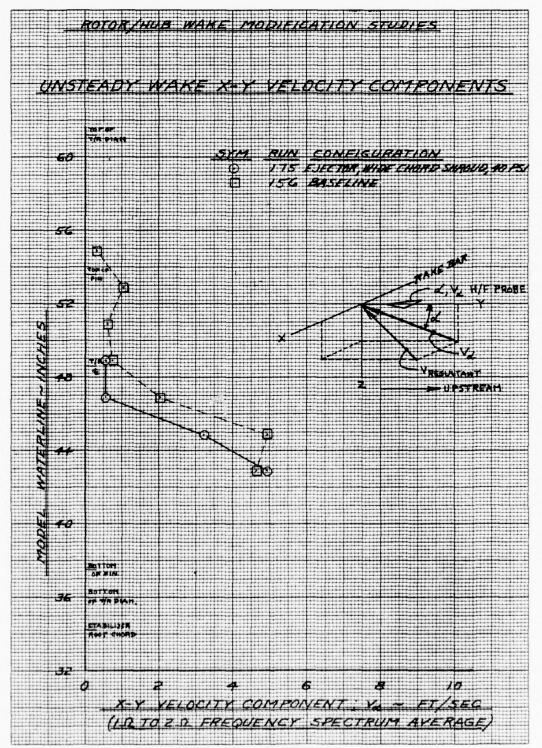


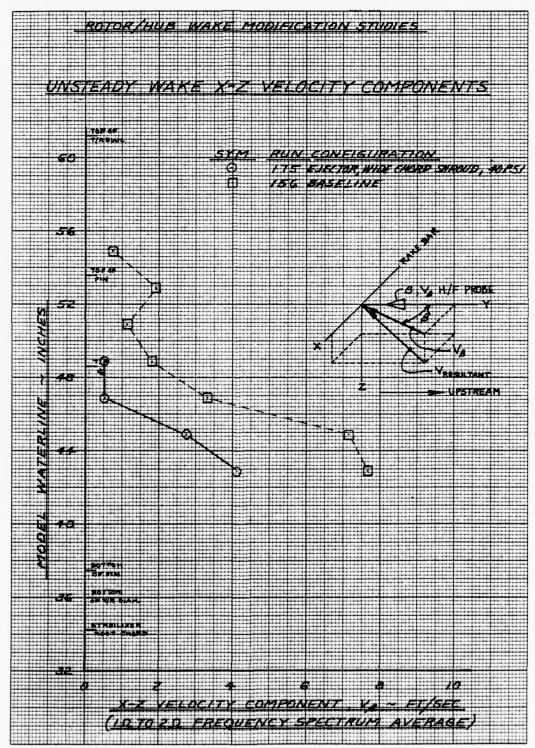


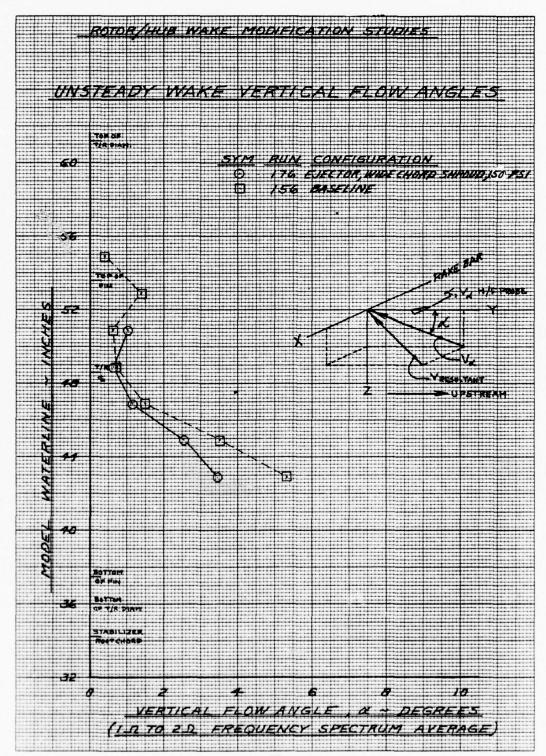


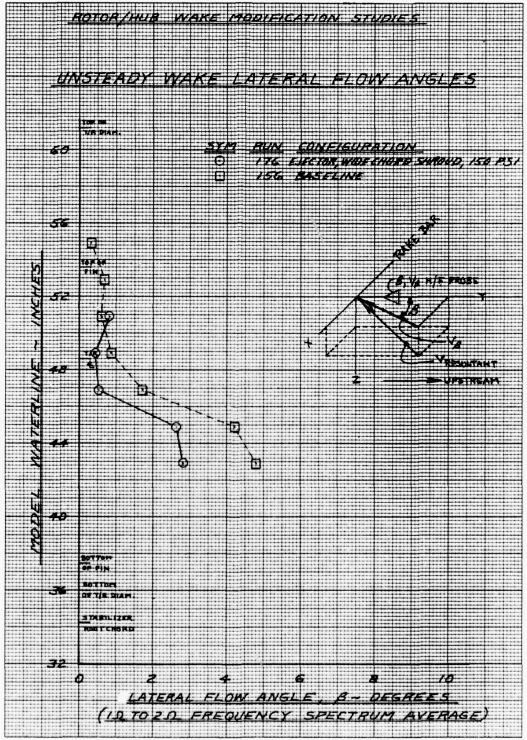


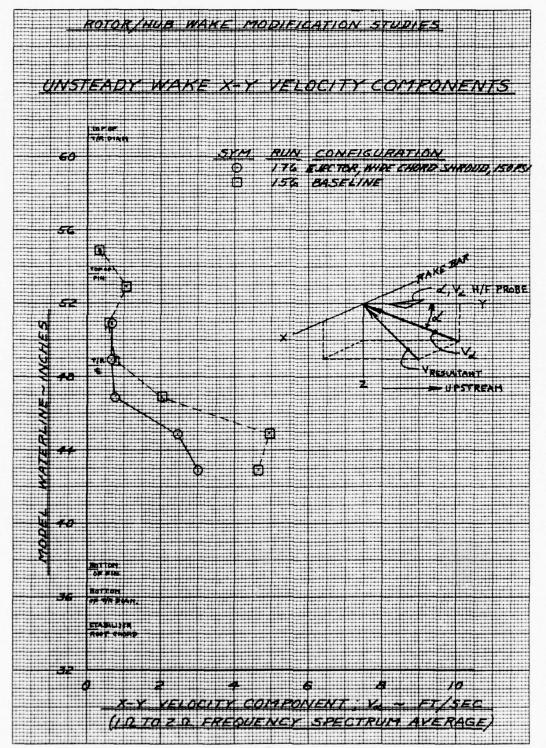


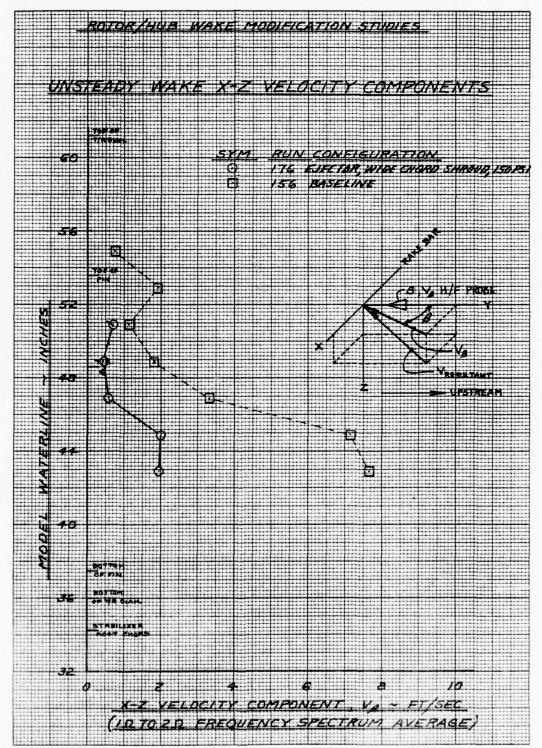


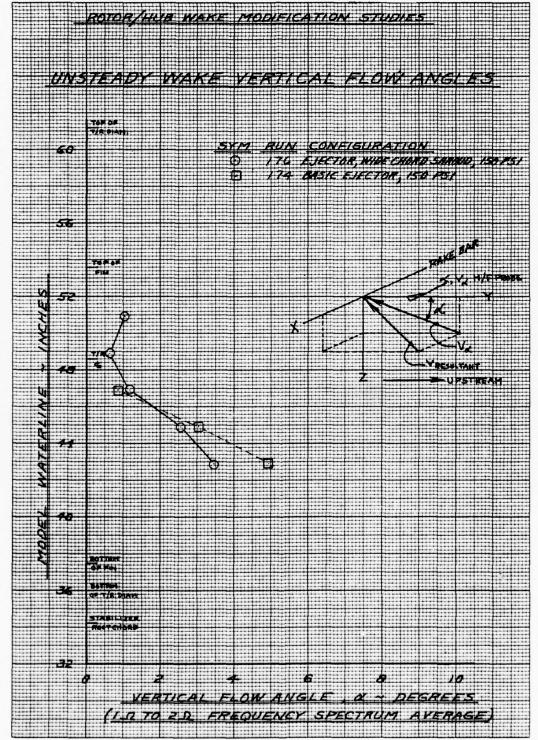


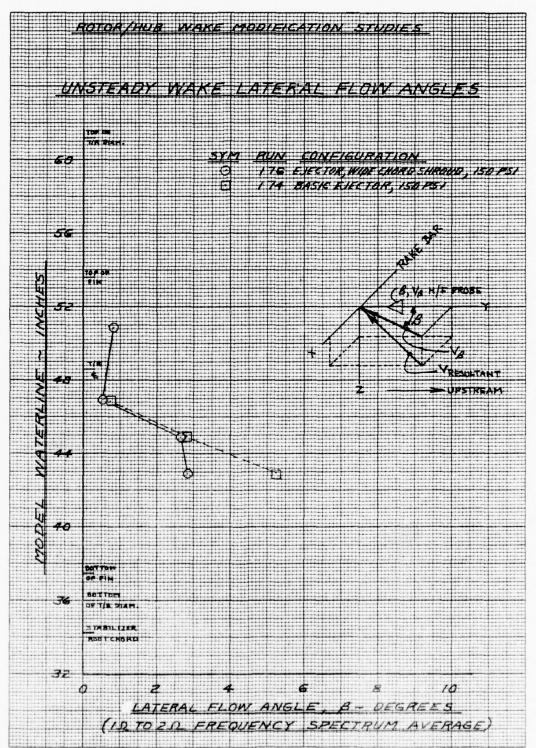


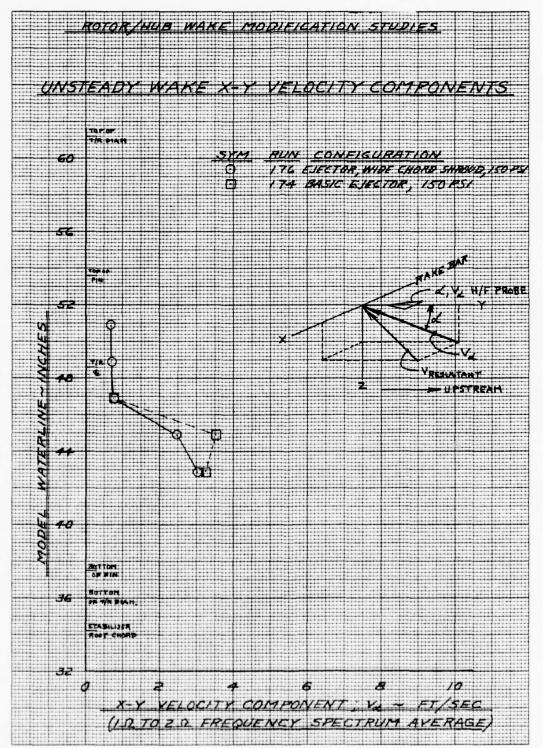


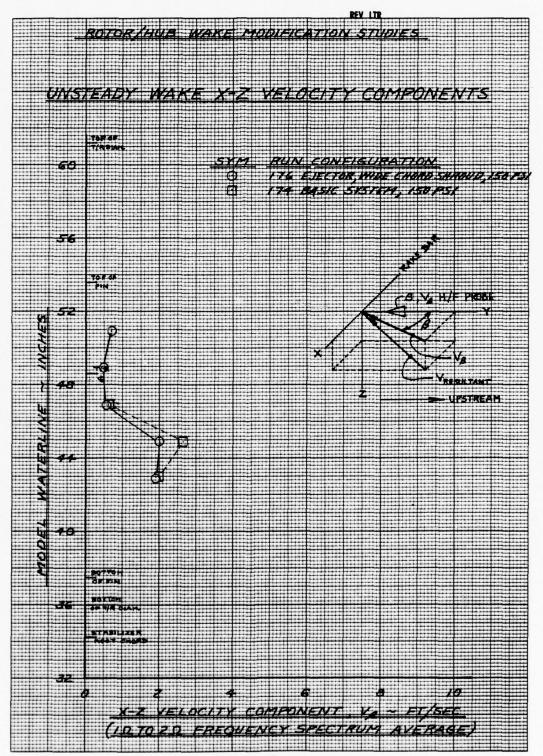


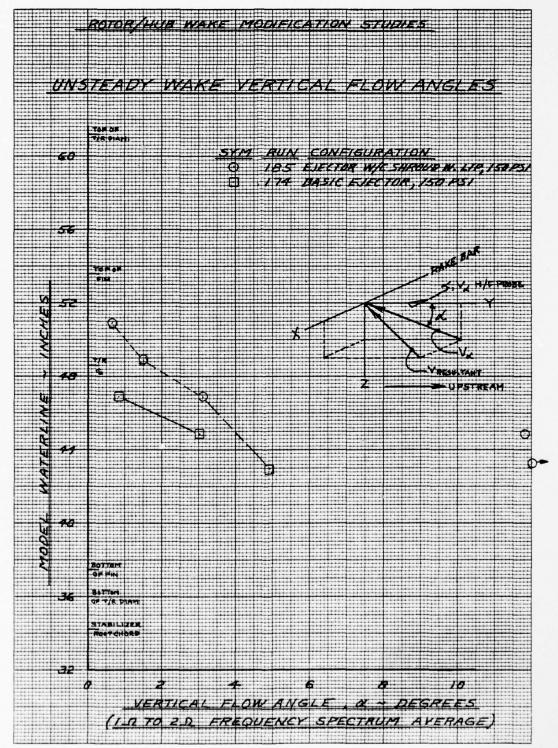


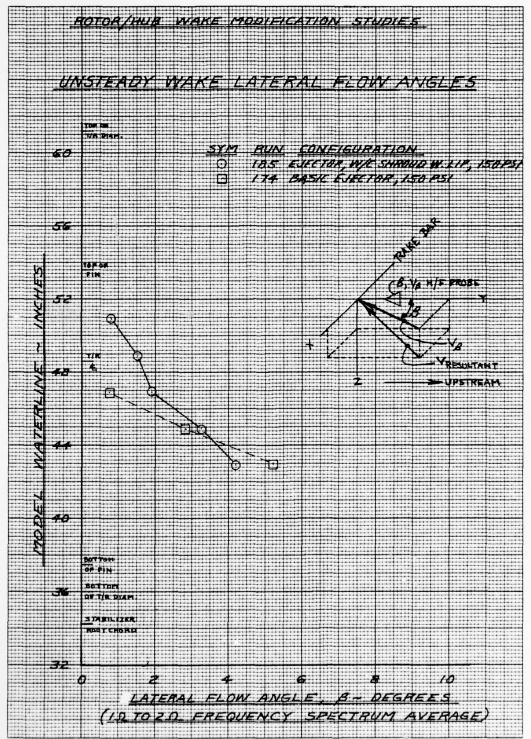


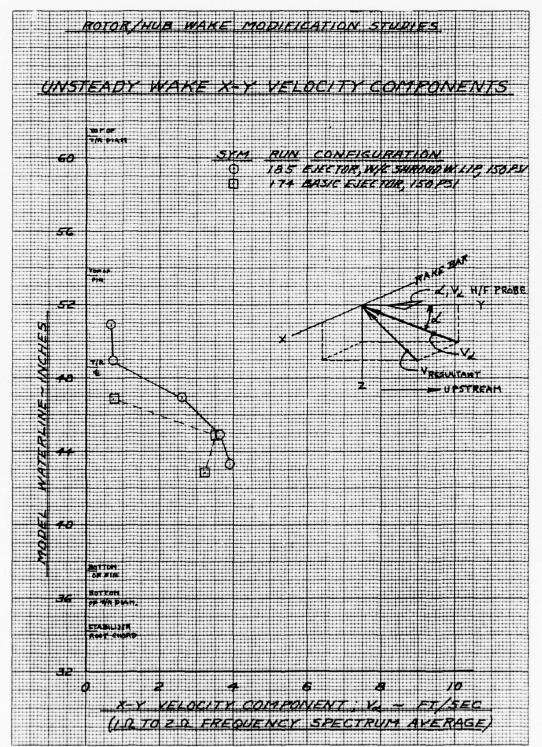


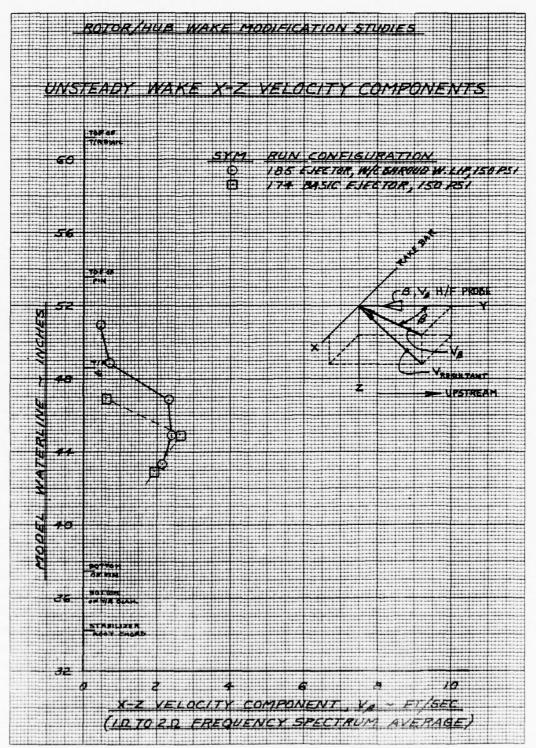


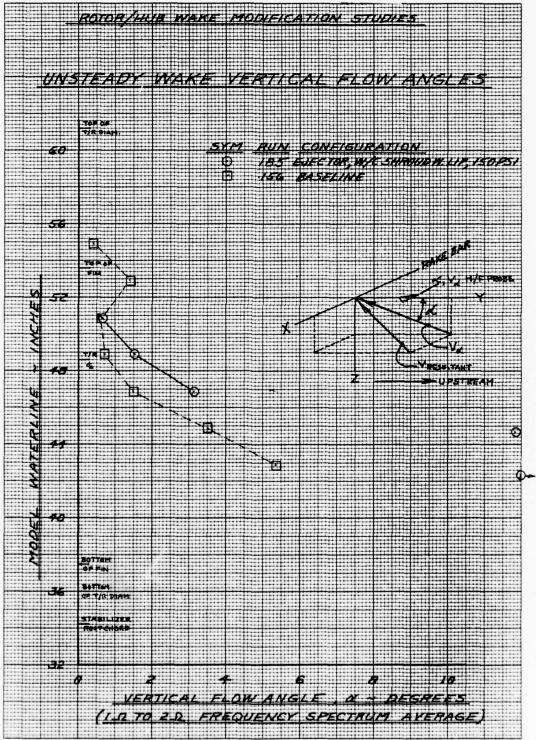


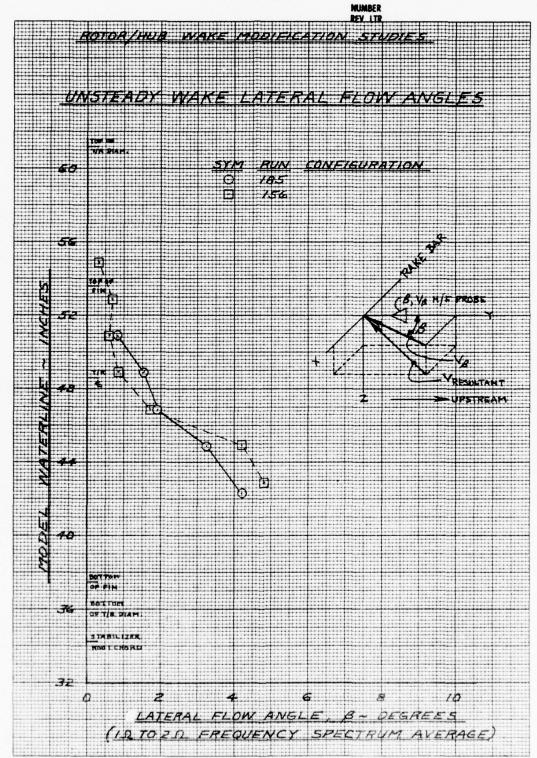


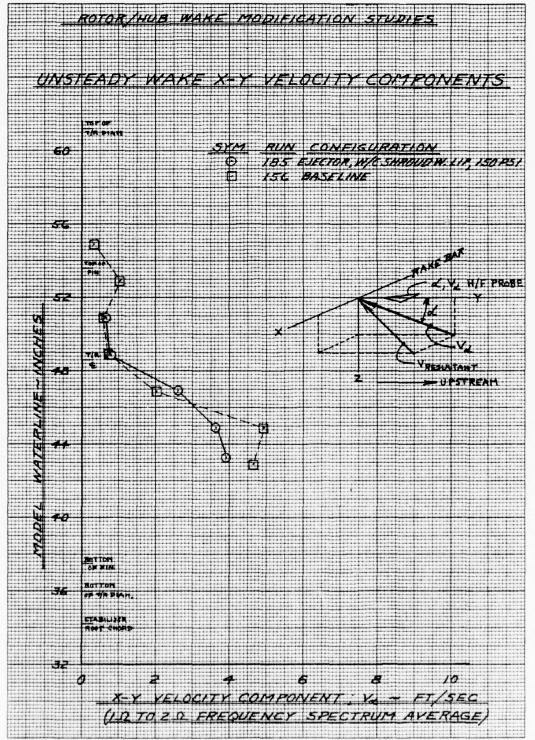


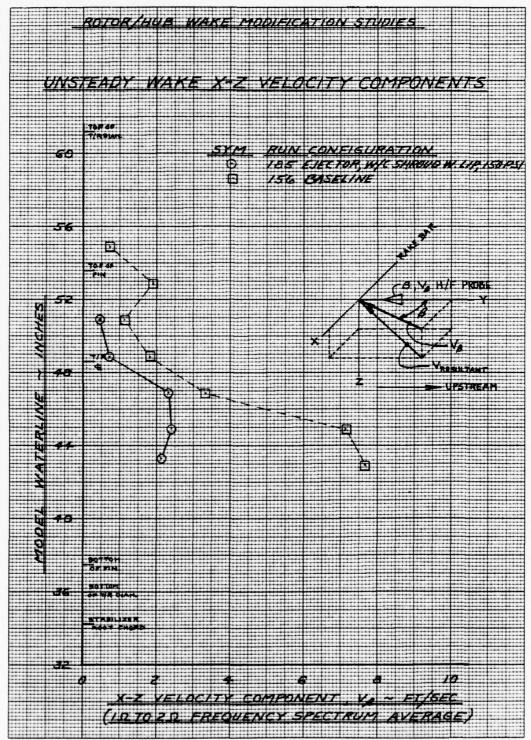


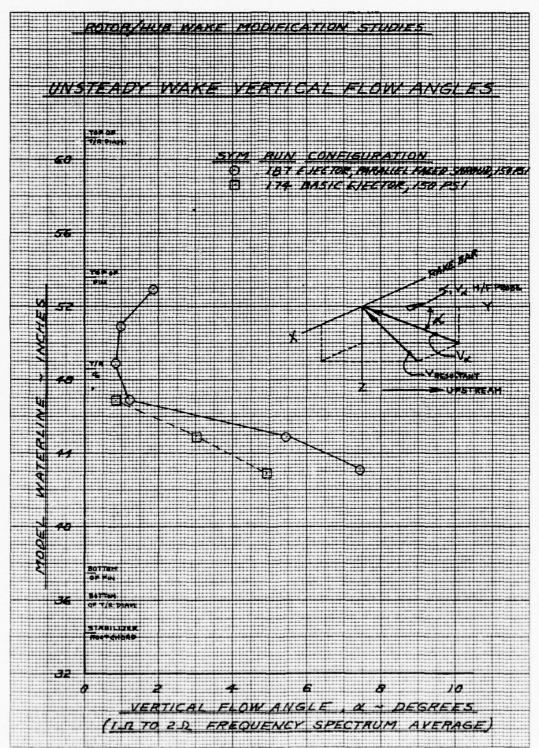


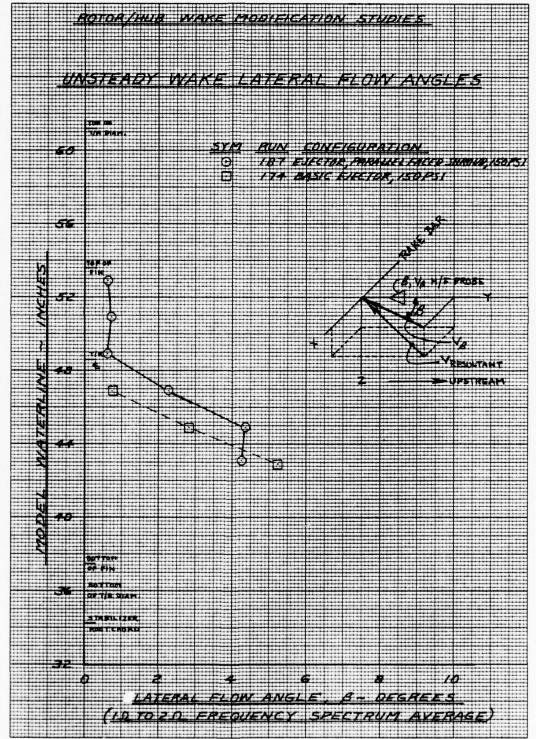


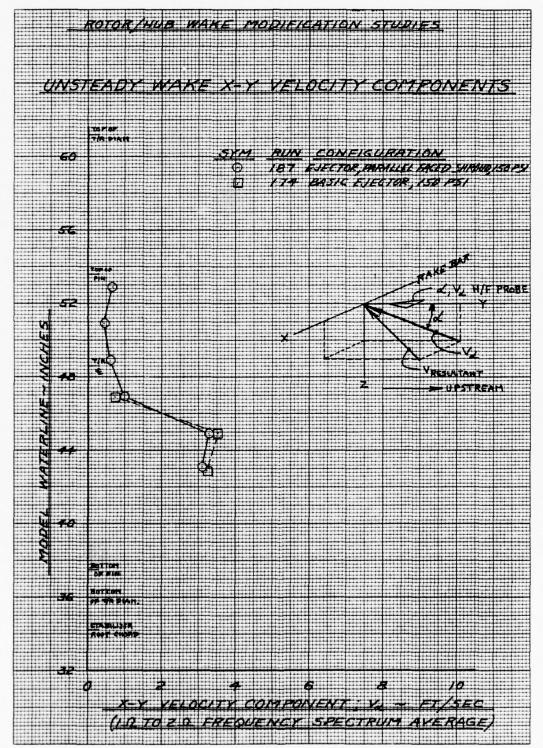


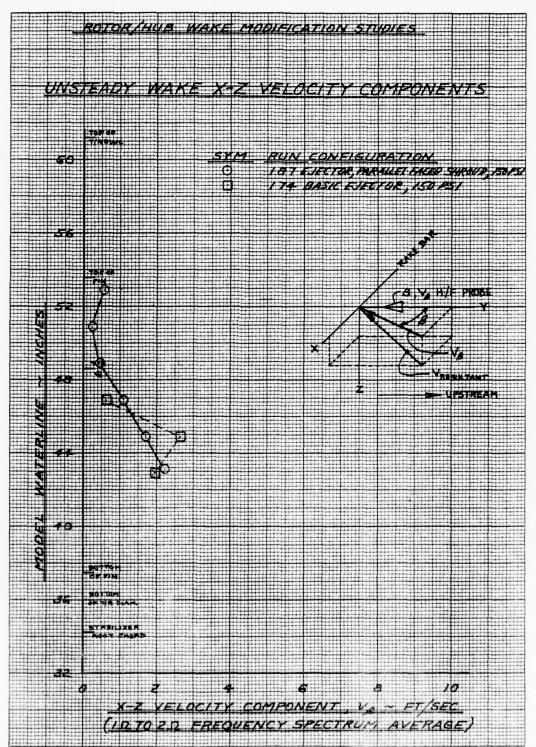


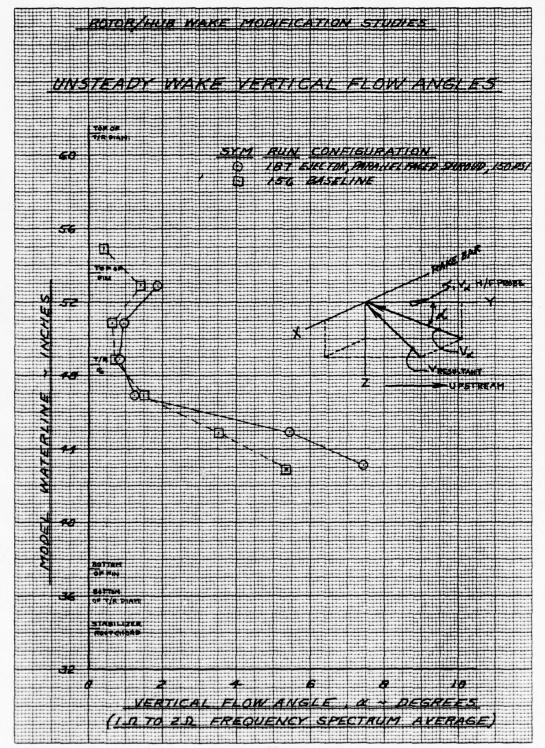


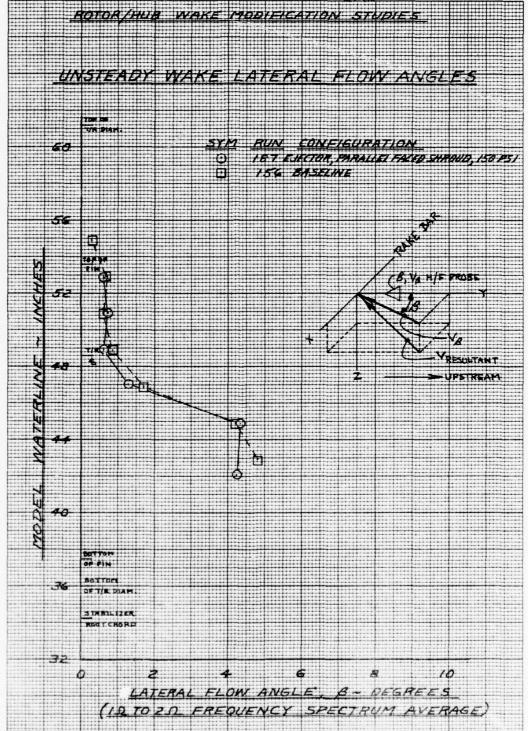


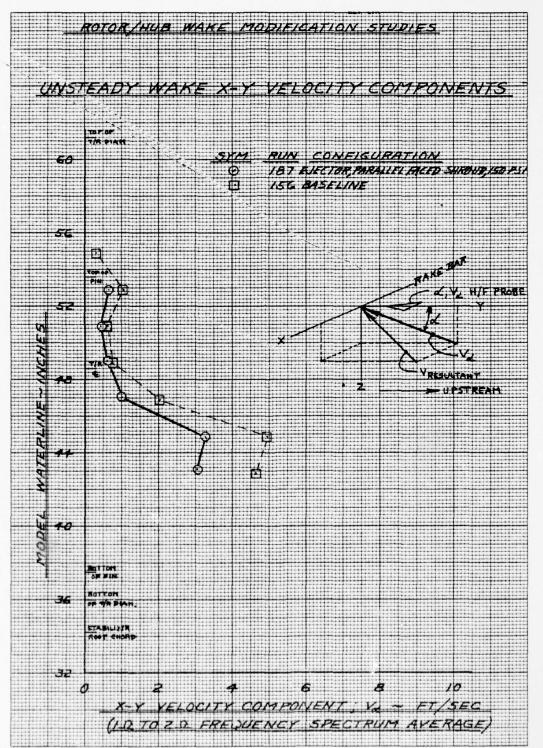


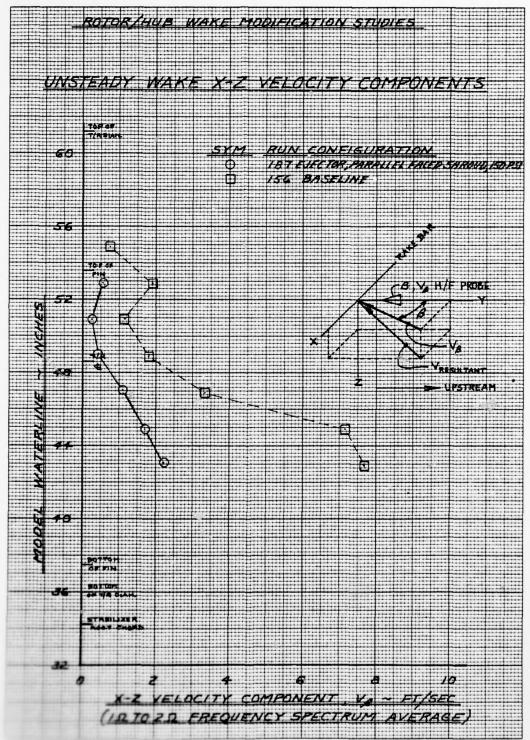


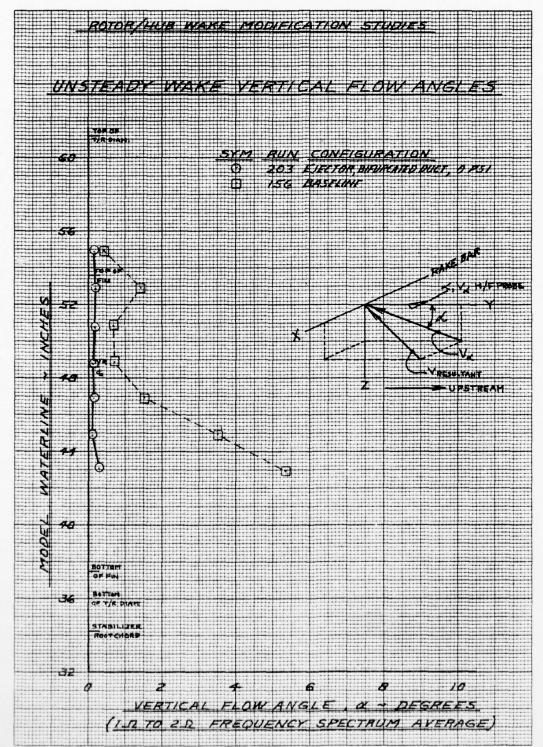


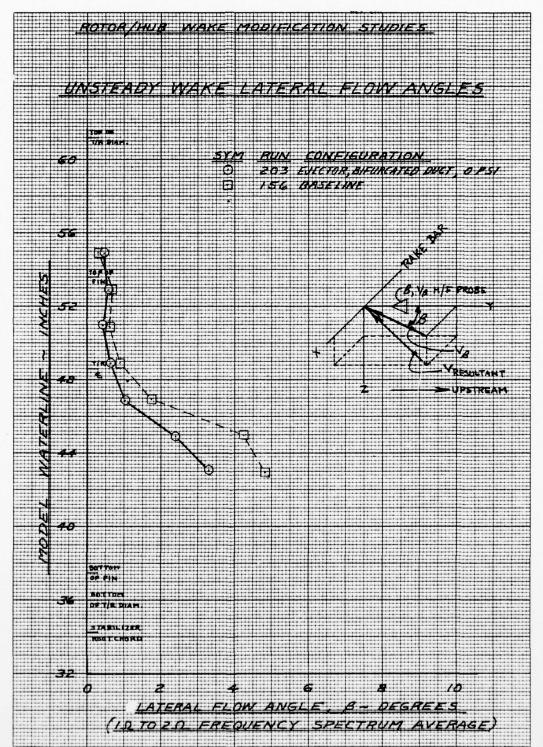


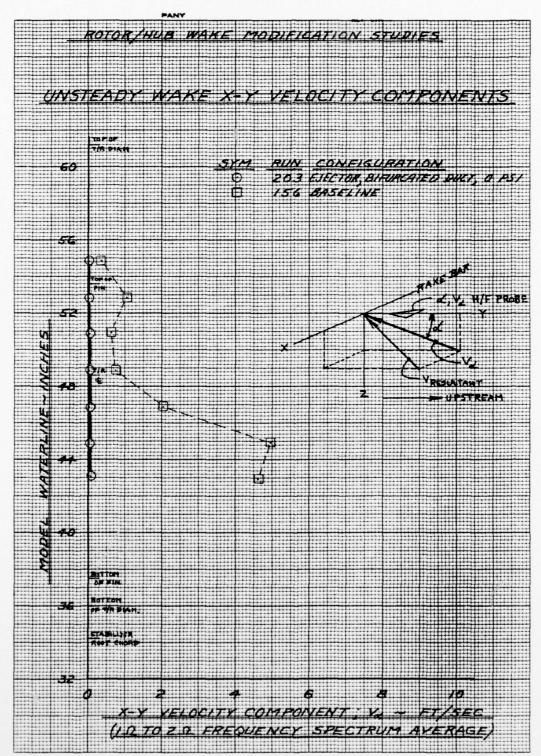


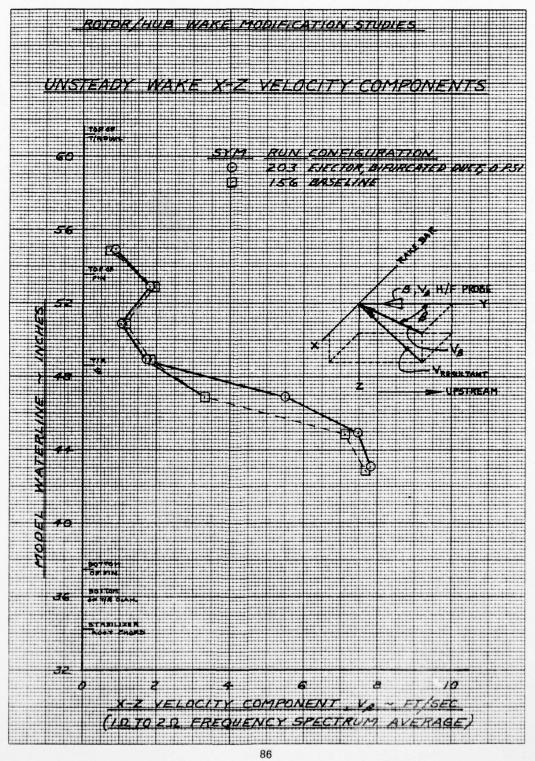


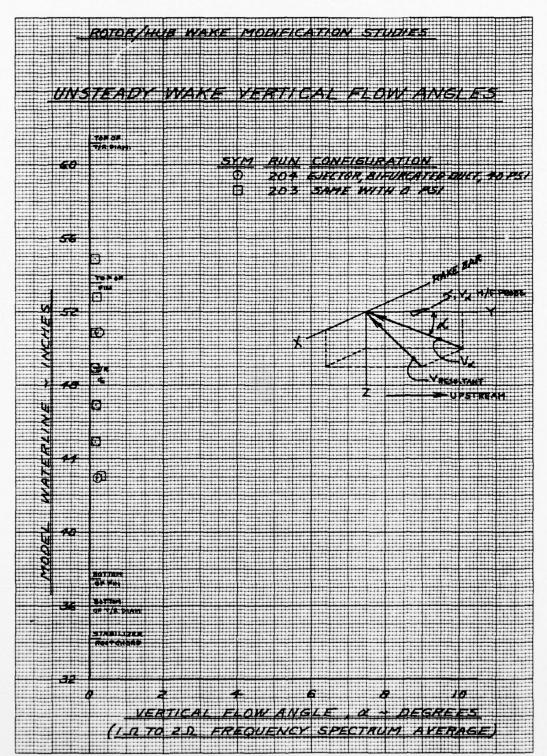


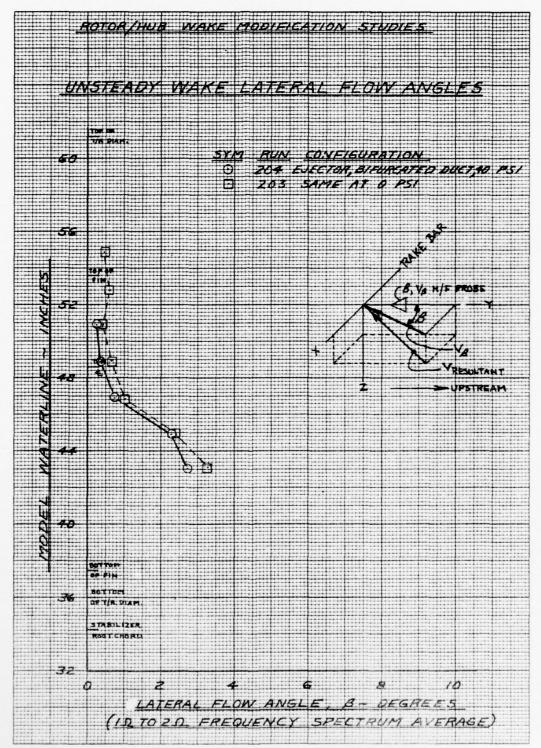


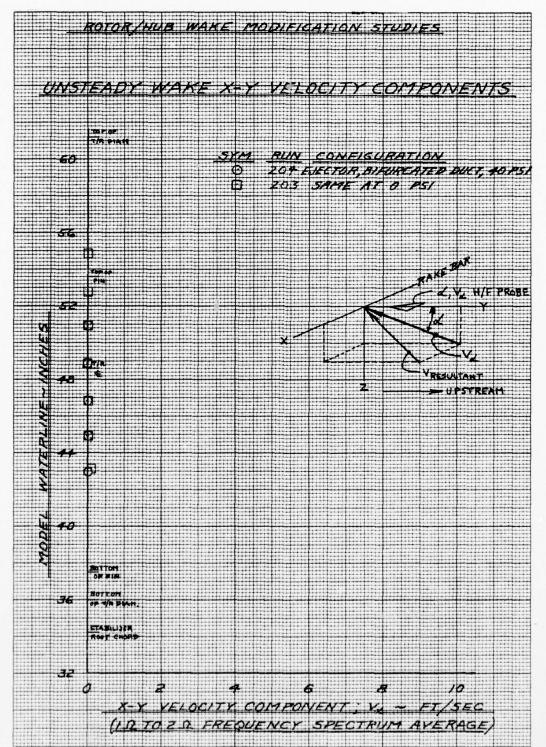


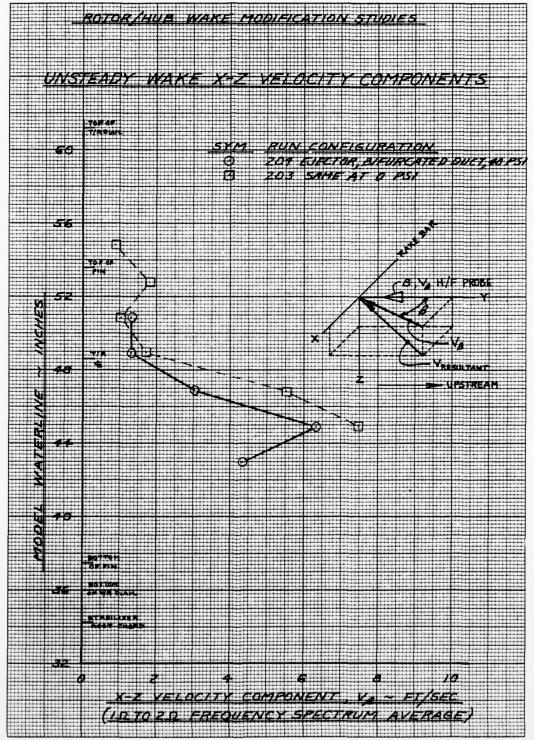


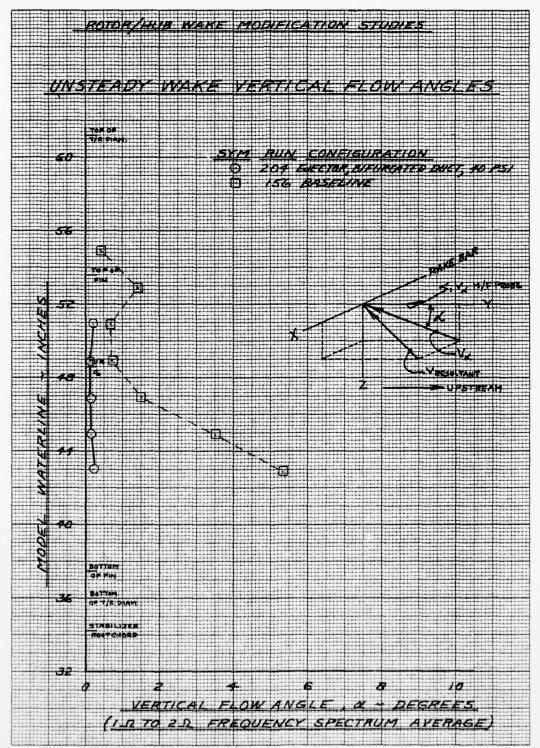


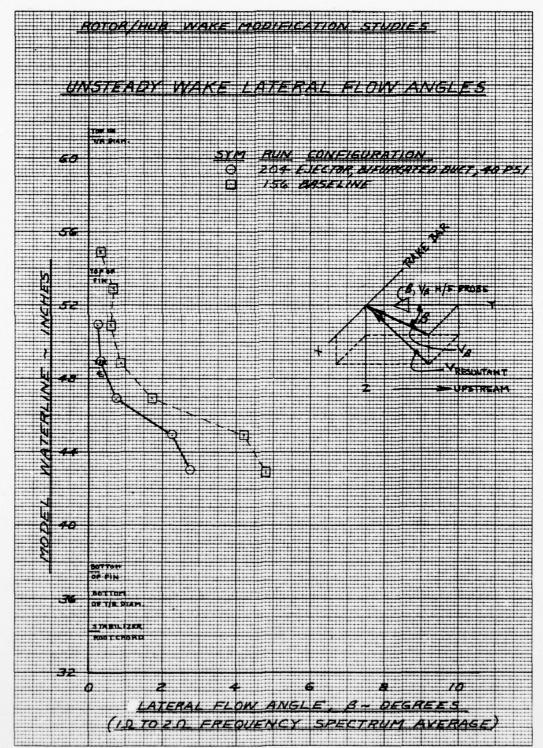


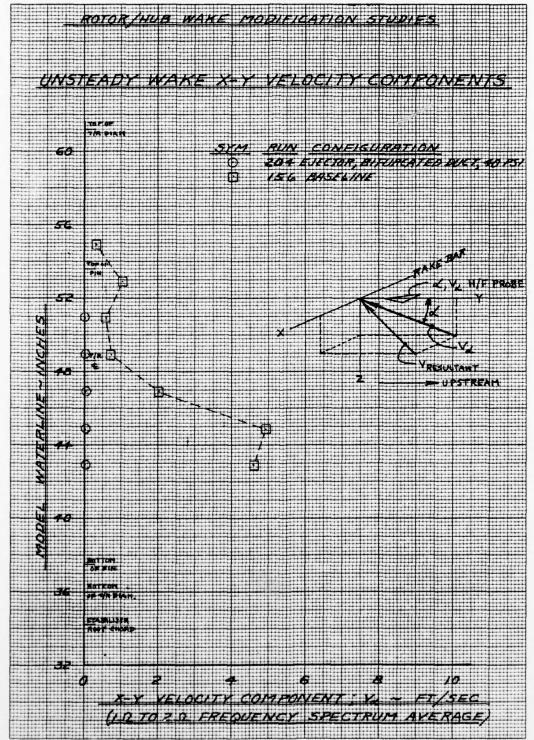


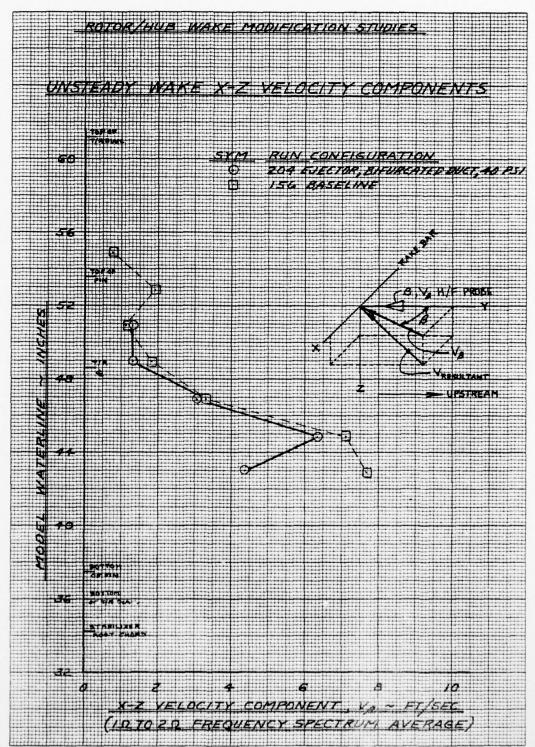


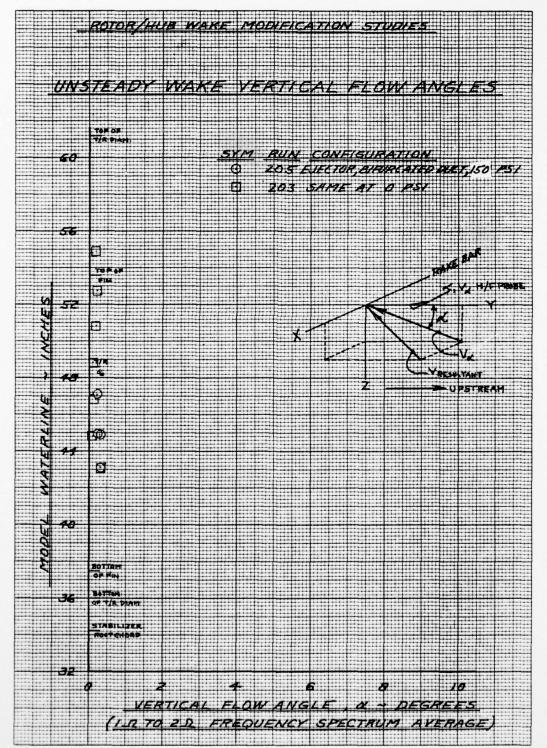




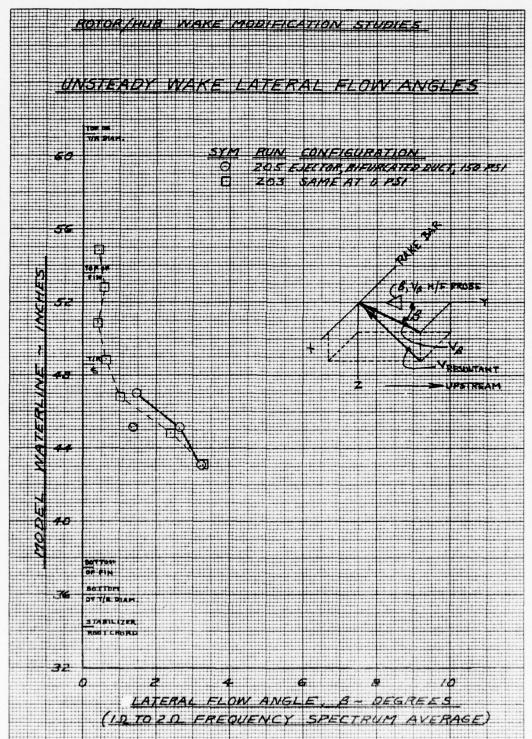


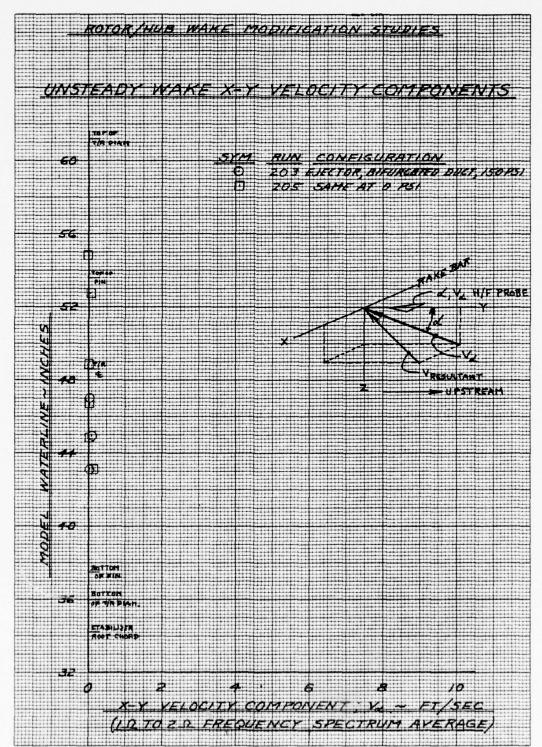


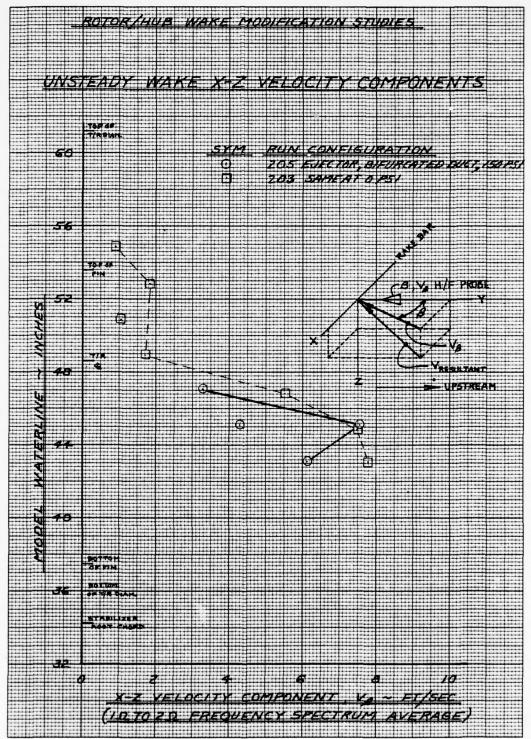


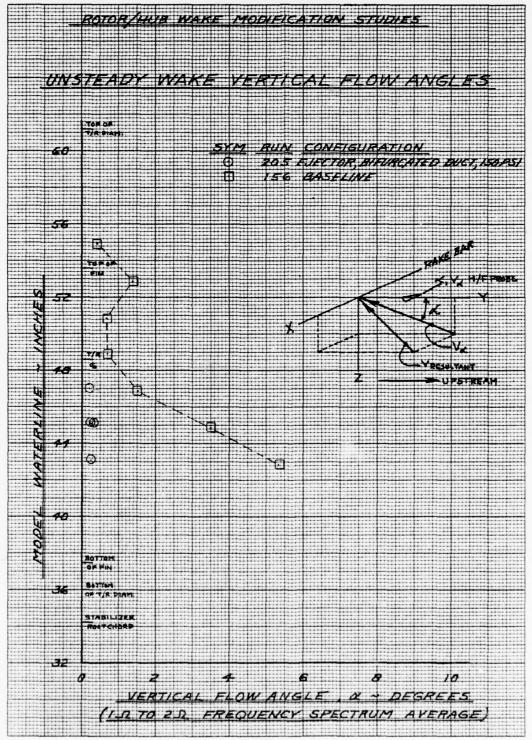


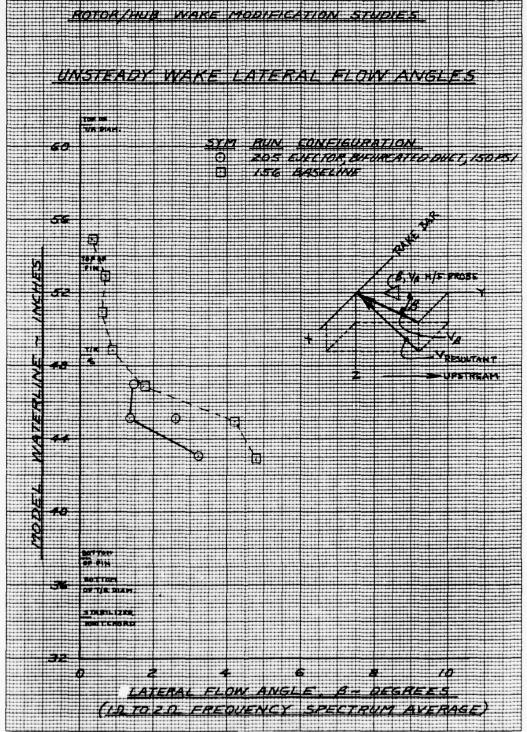
BOEING VERTOL CO PHILADELPHIA PA F/6 1/3
INTERACTIONAL AERODYNAMICS OF THE SINGLE ROTOR HELICOPTER CONFI--ETC(U) AD-A061 767 DAAJ02-77-C-0020 SEP 78 P F SHERIDAN USARTL-TR-78-23C-VOL-3B NL UNCLASSIFIED 2053 AD A061767

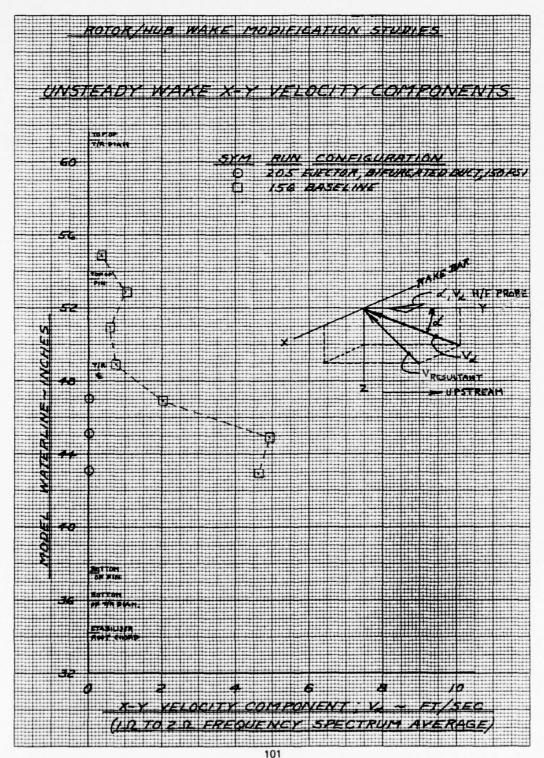


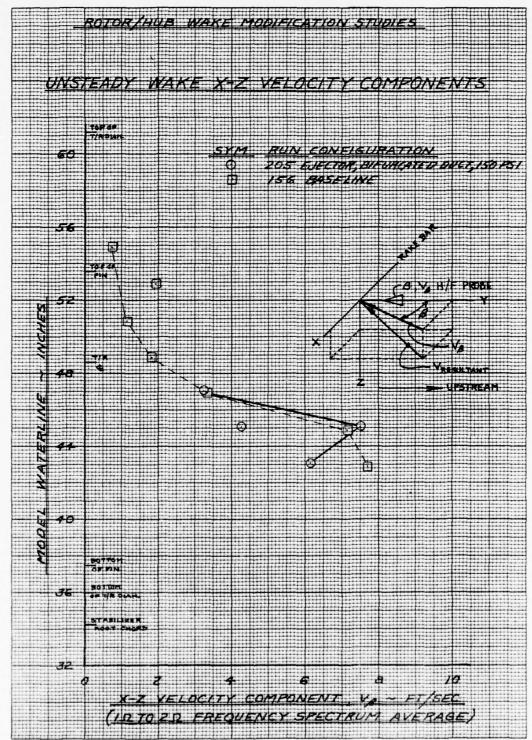


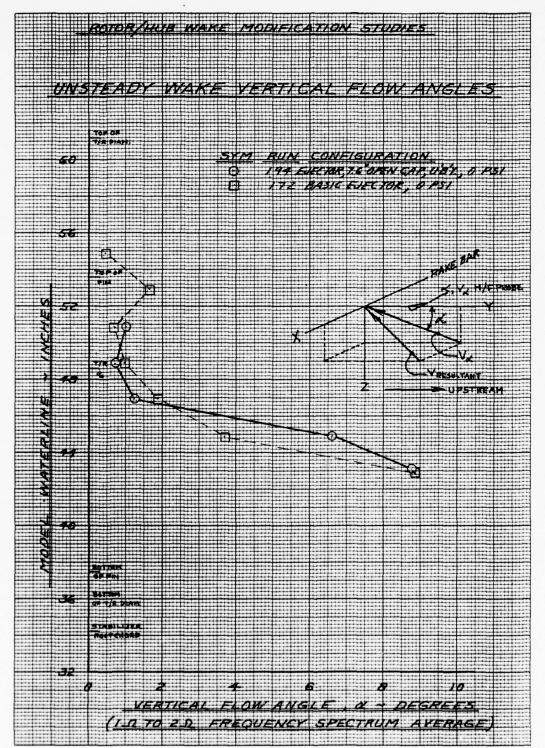


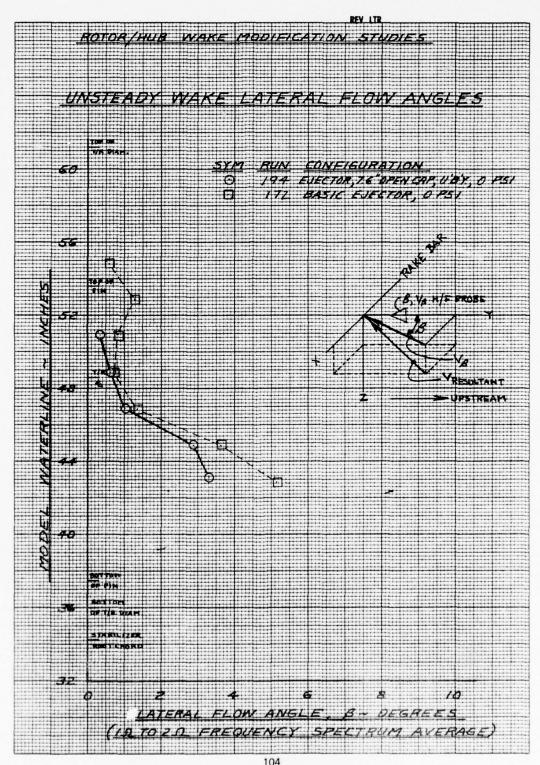


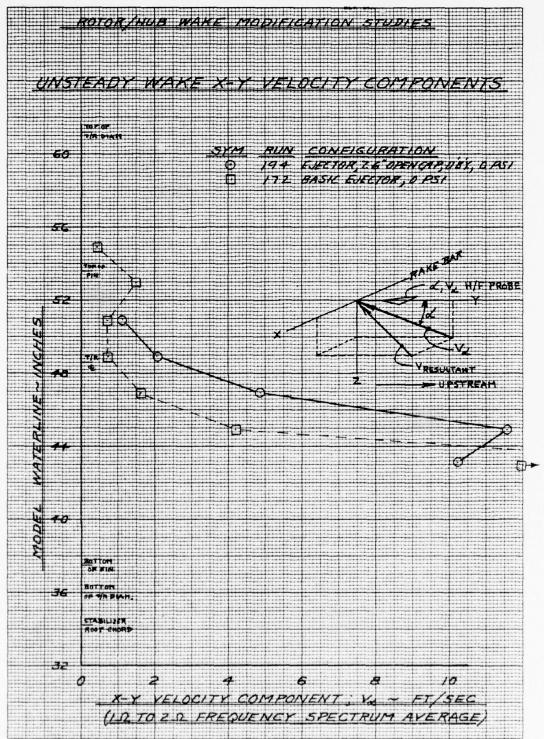


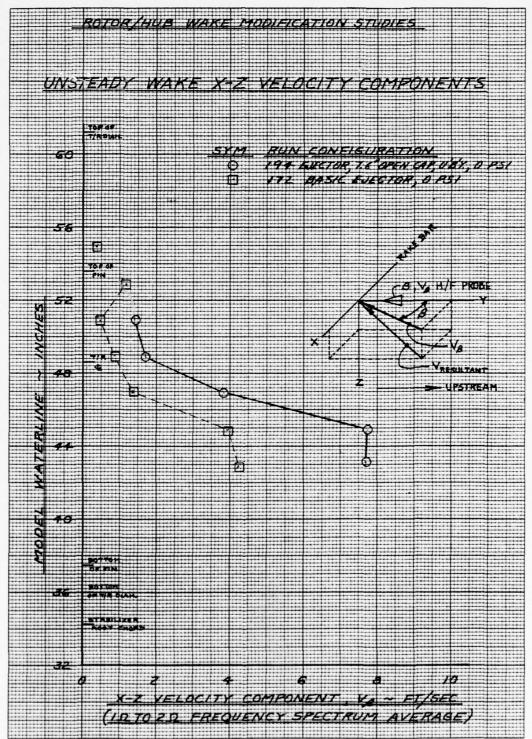


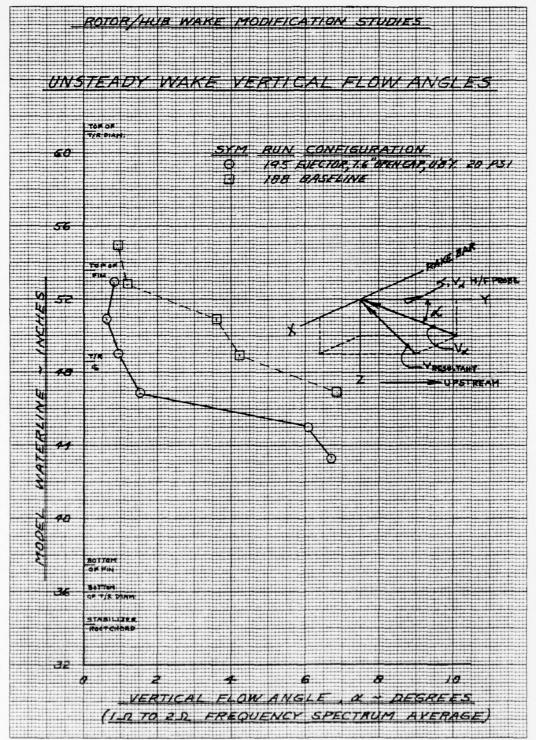


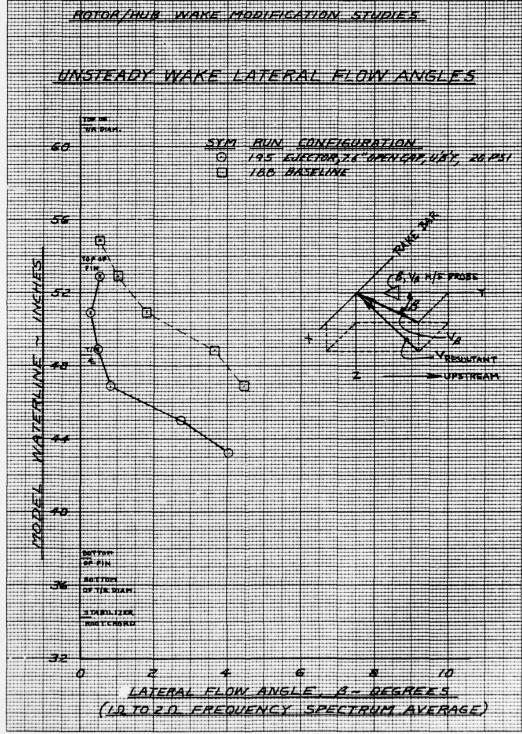


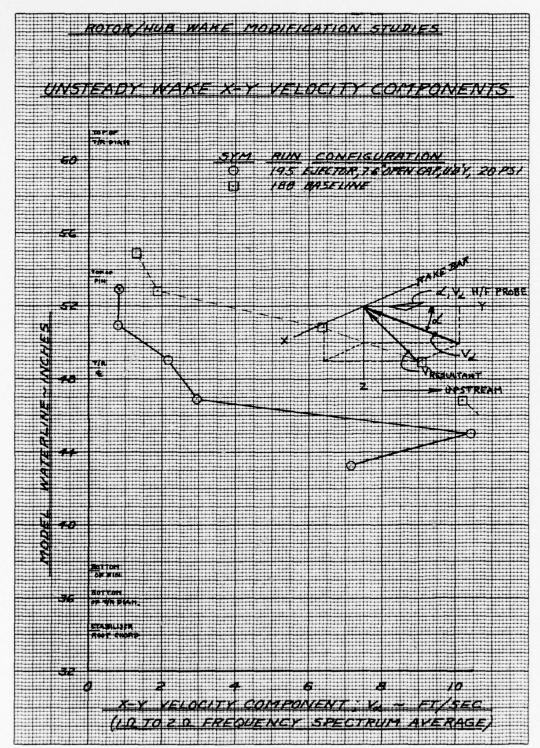


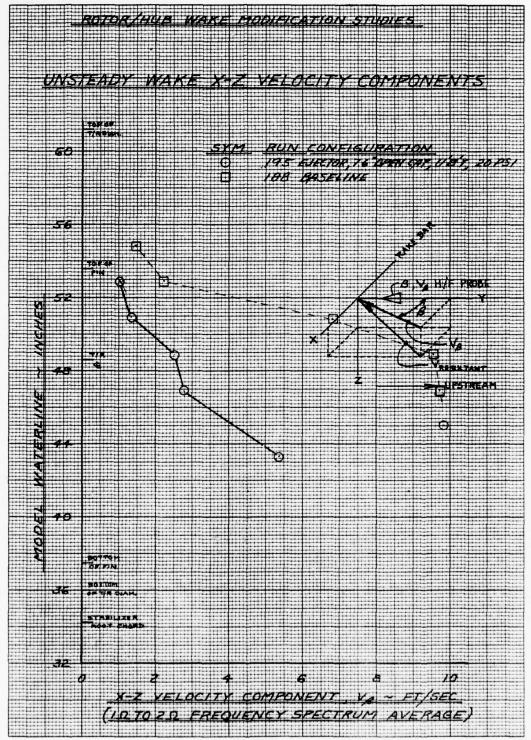


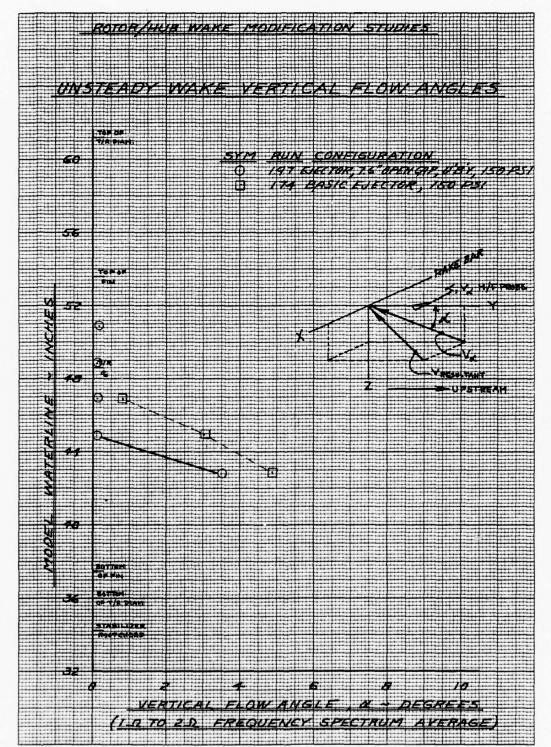


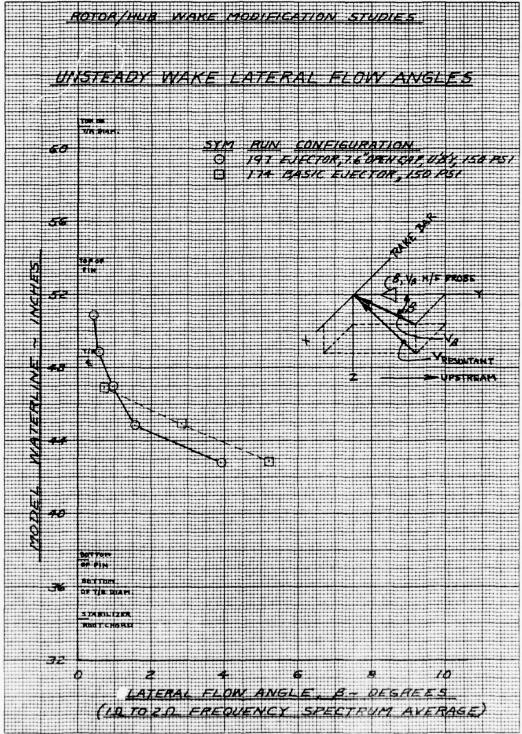


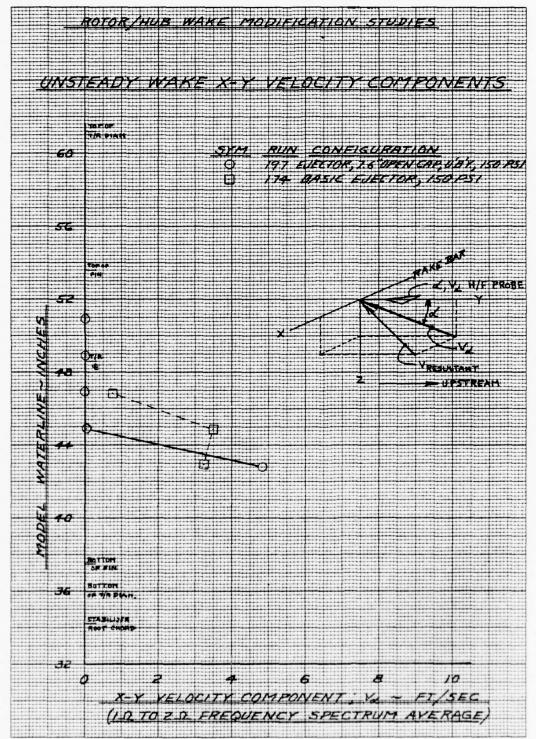


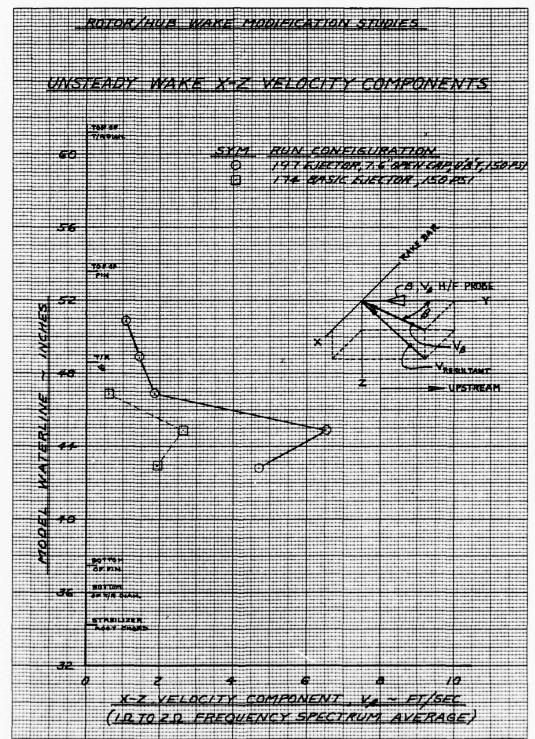


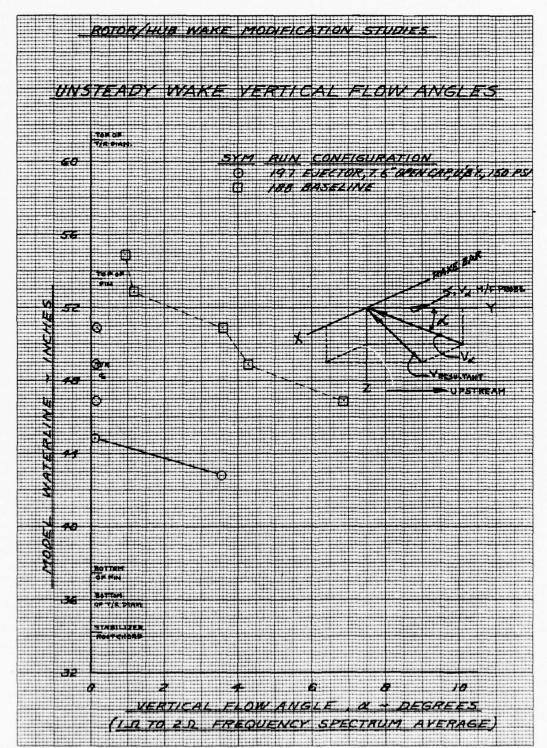


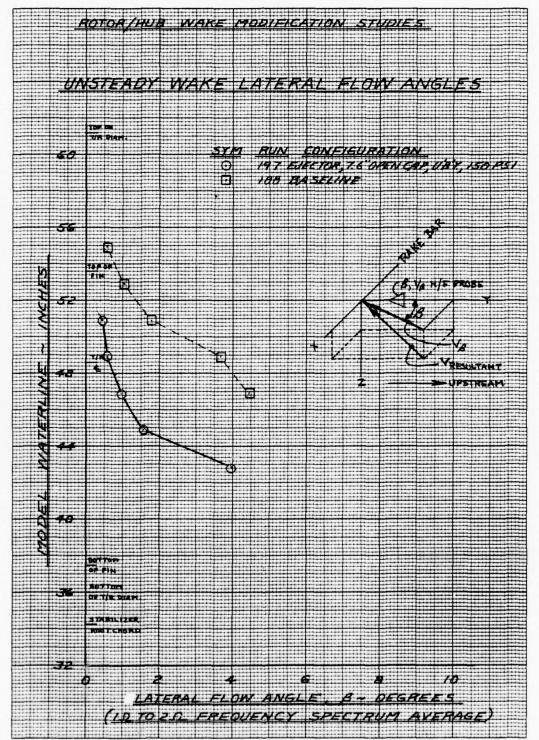


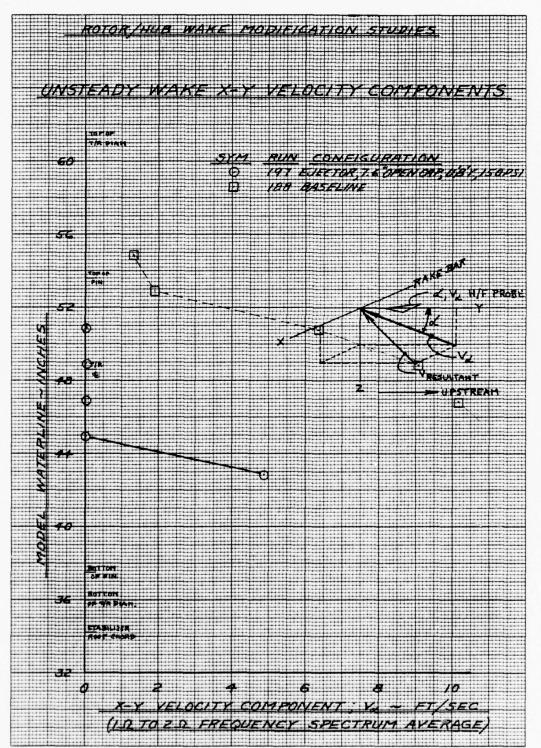


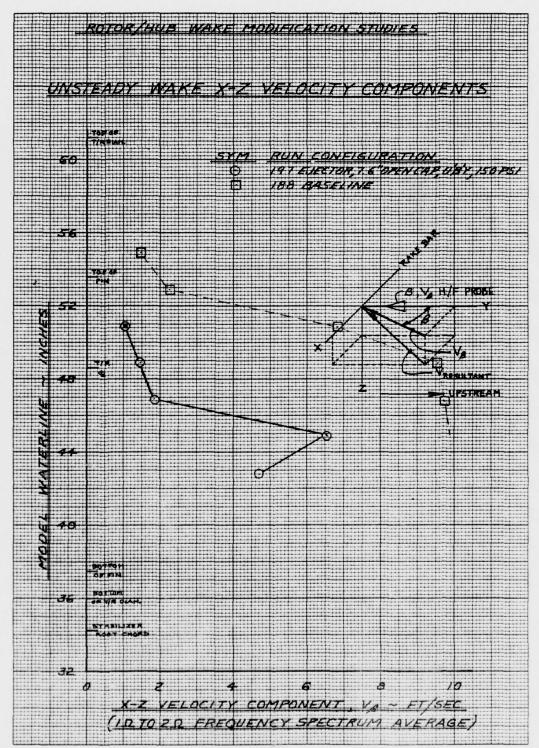


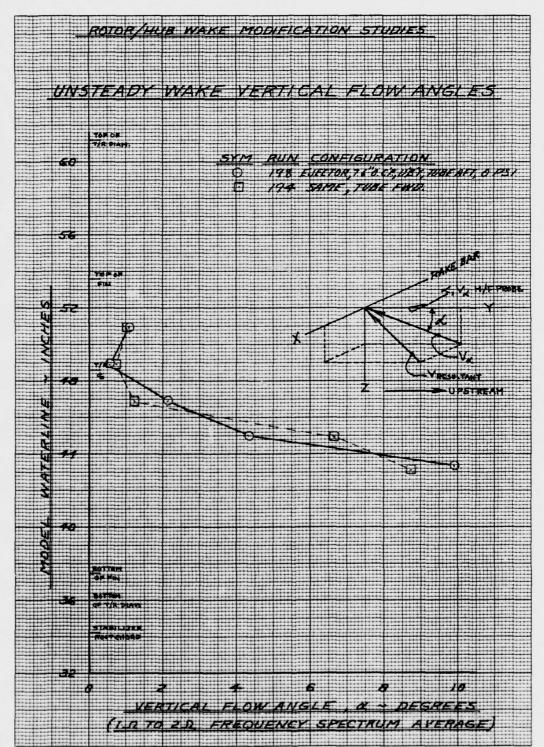


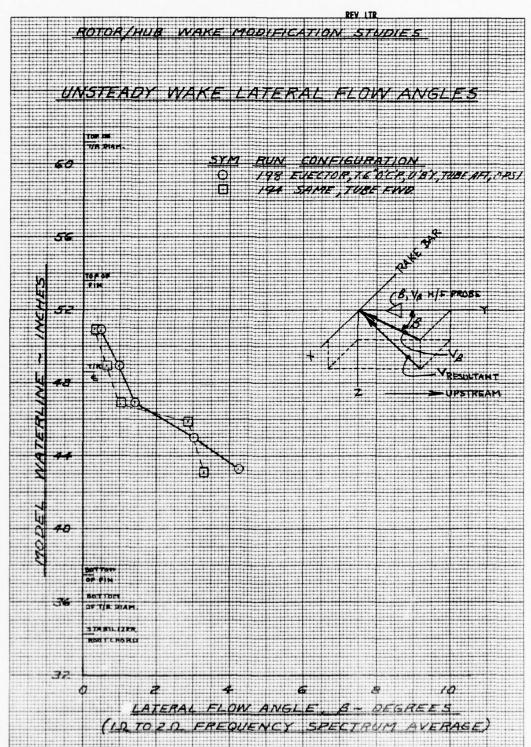


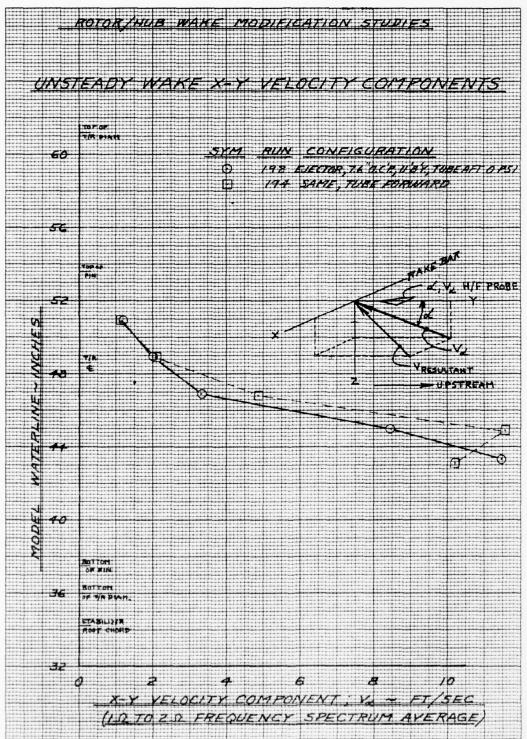


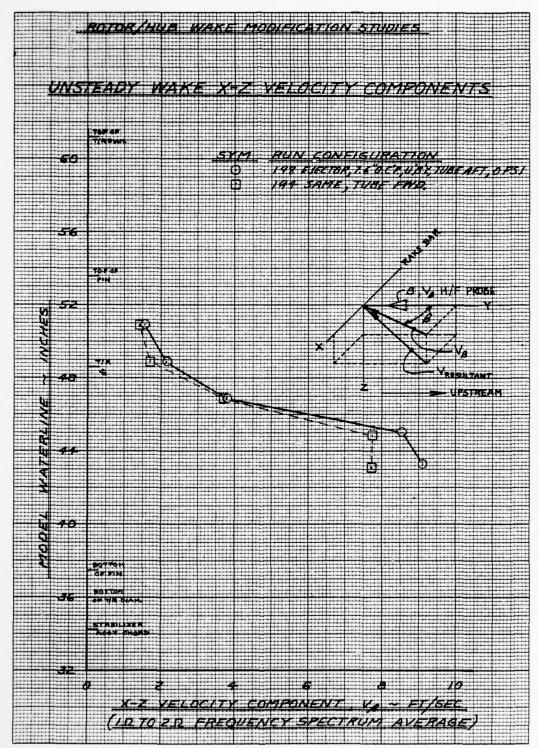


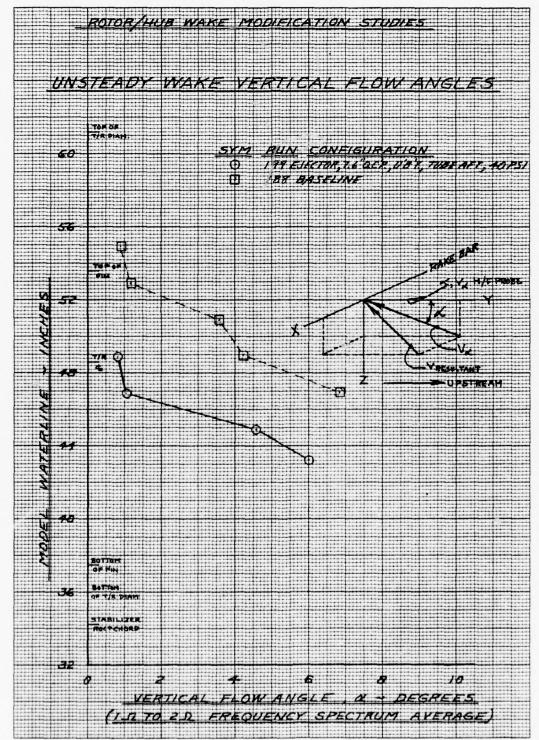


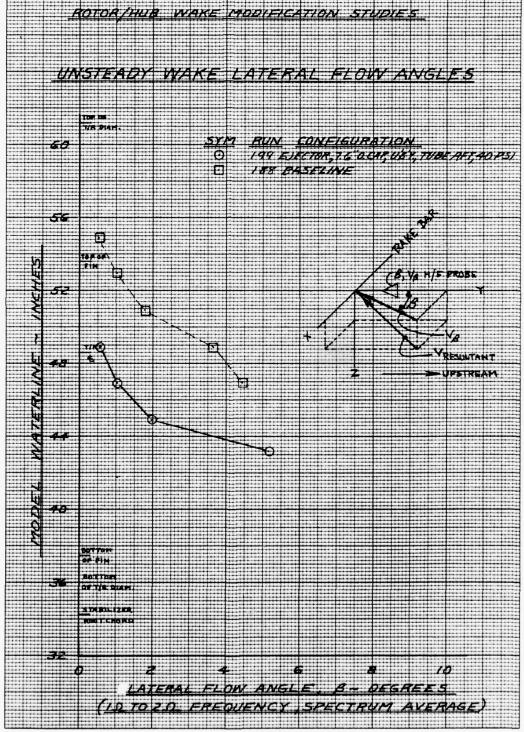


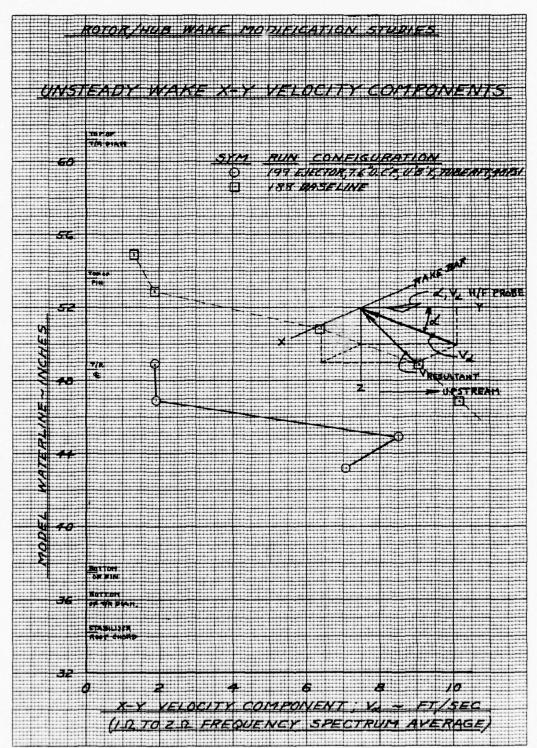


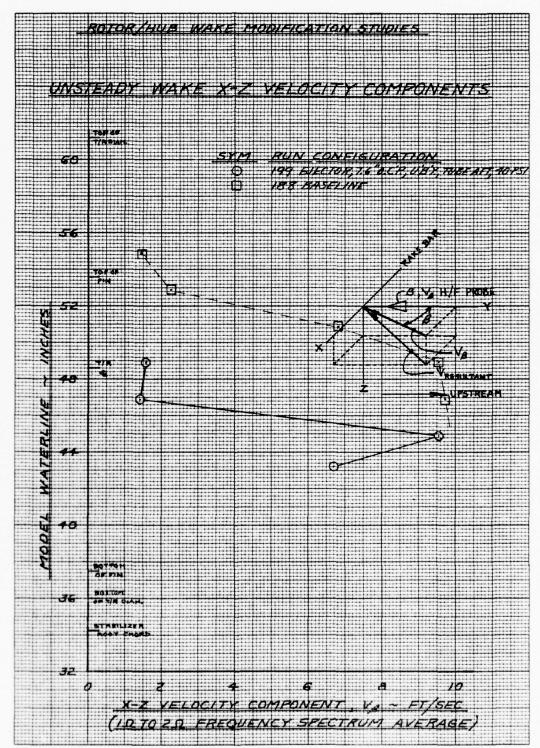


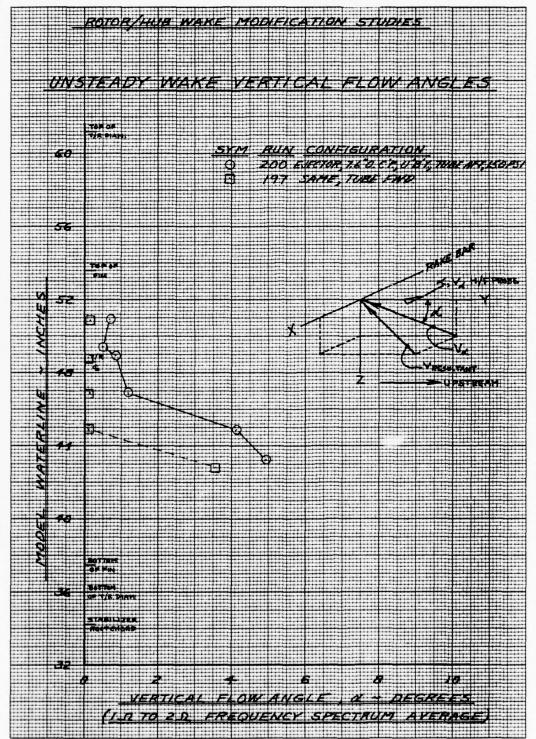


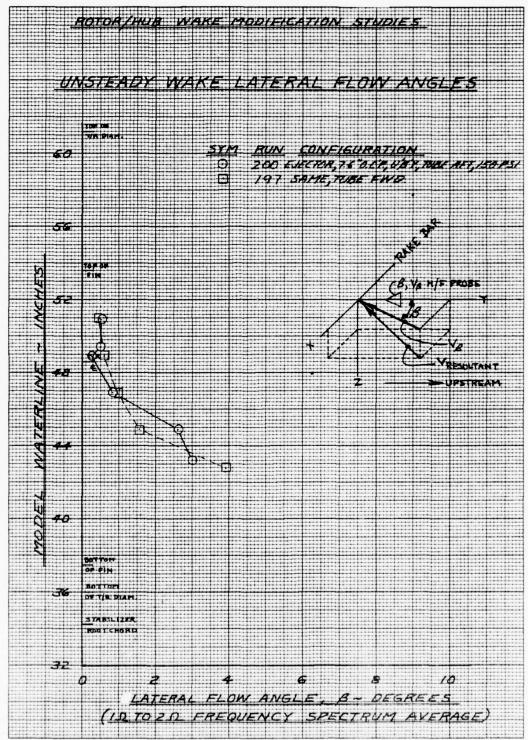


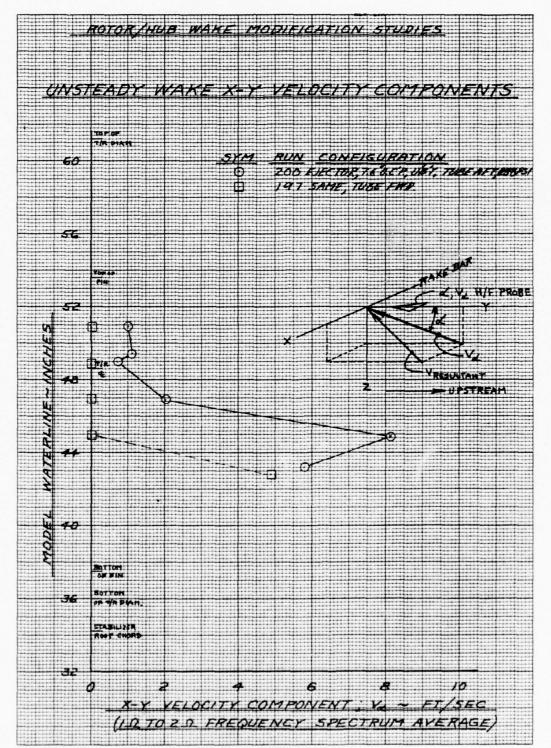


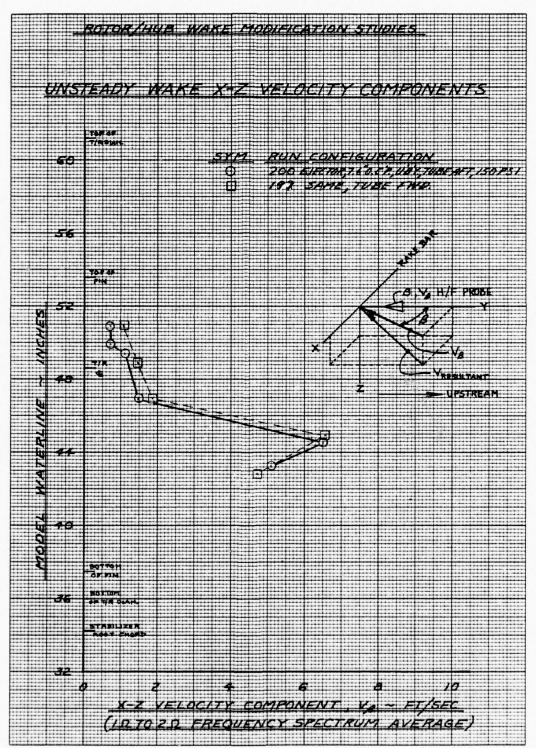


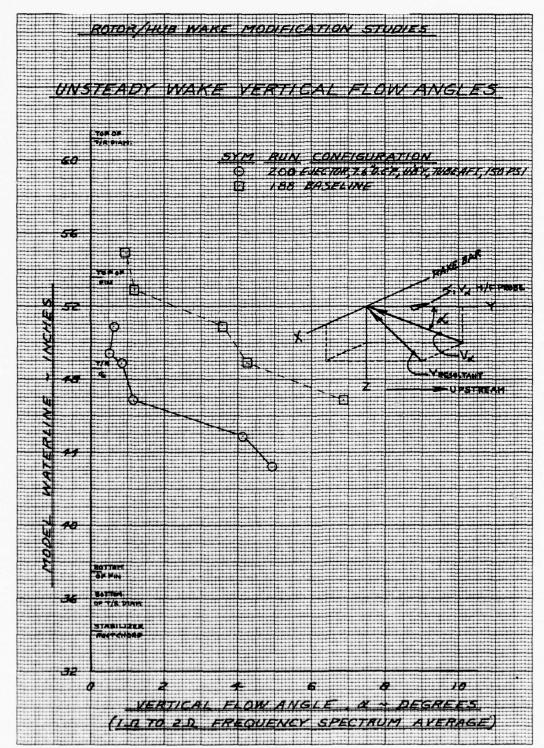


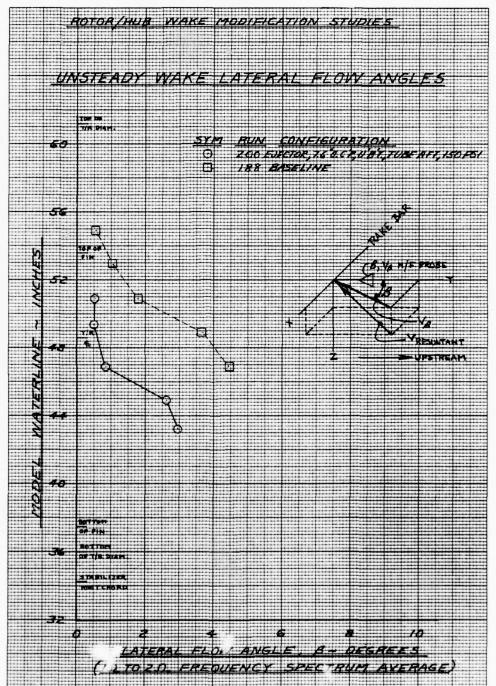


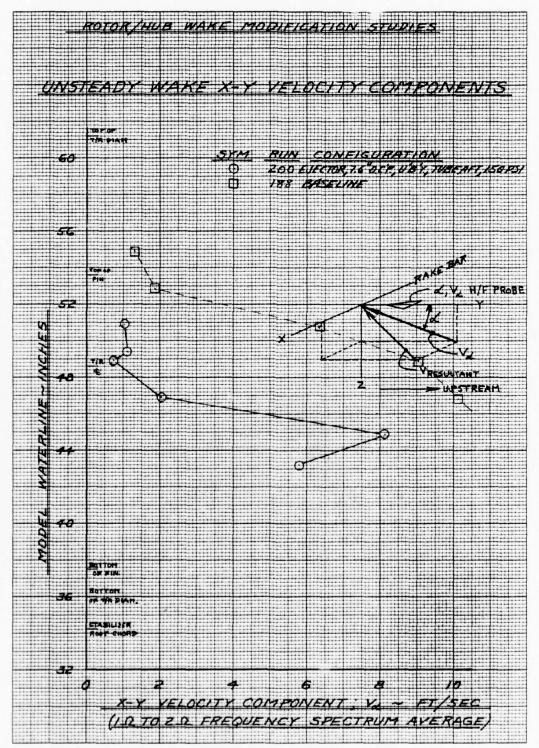


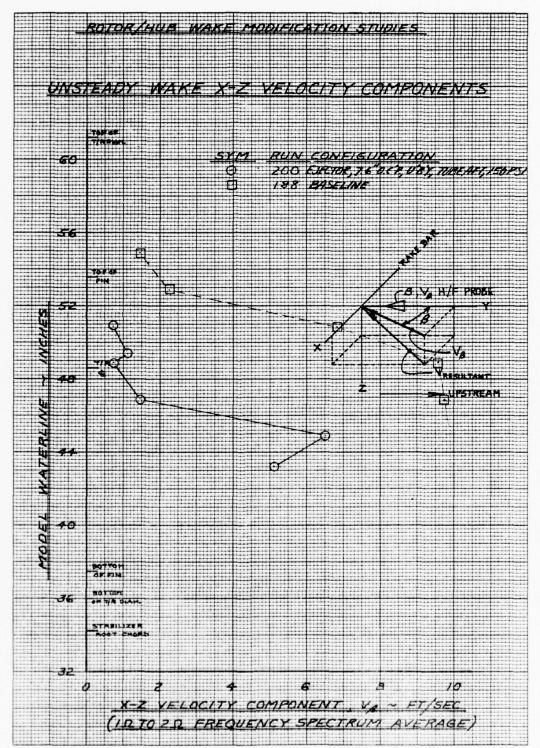


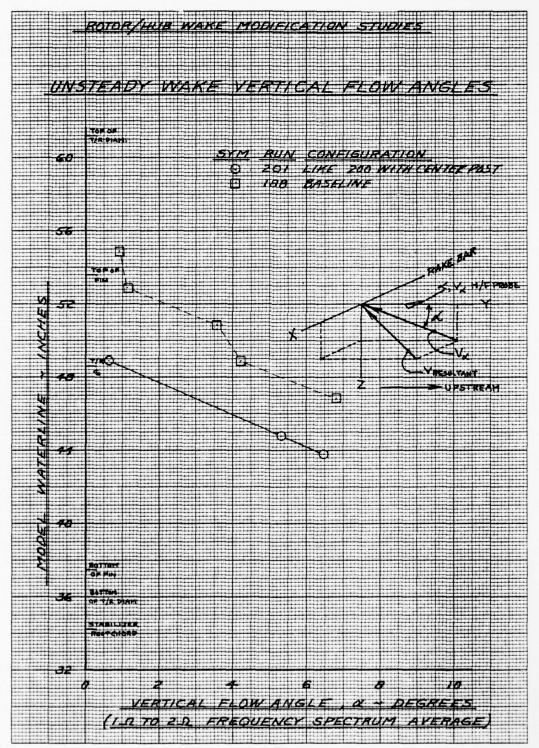


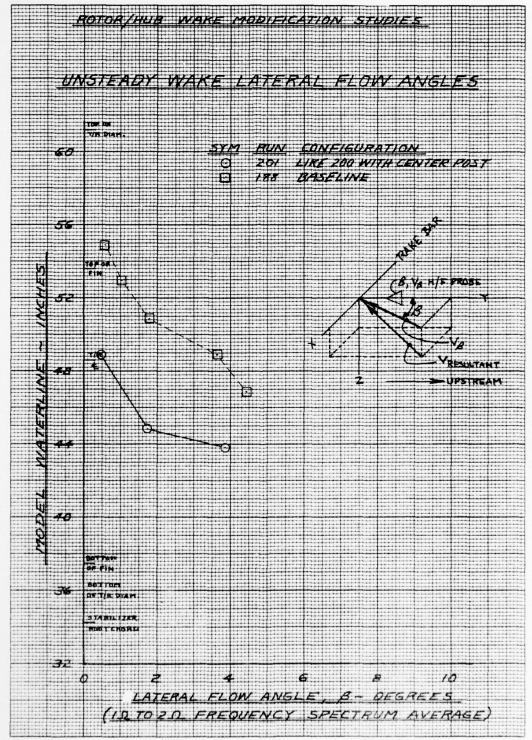


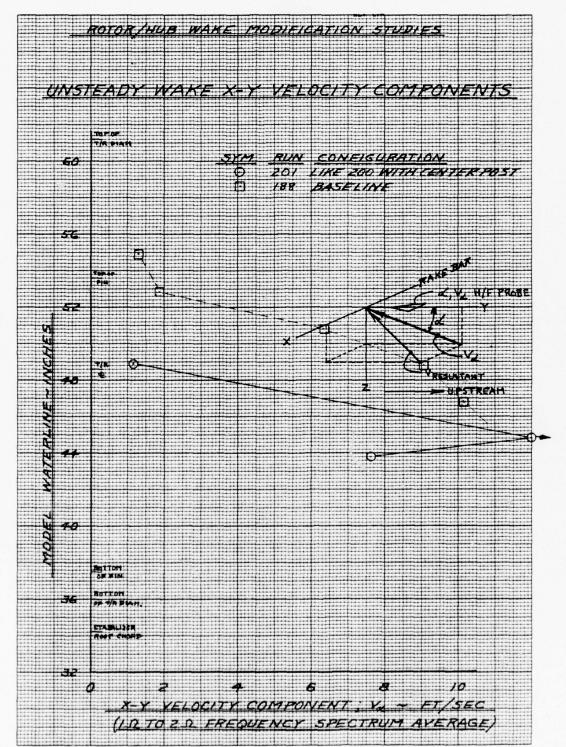


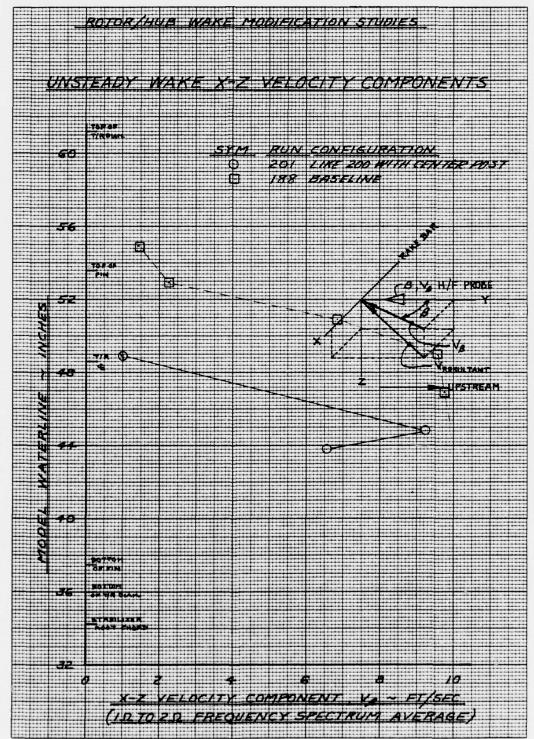


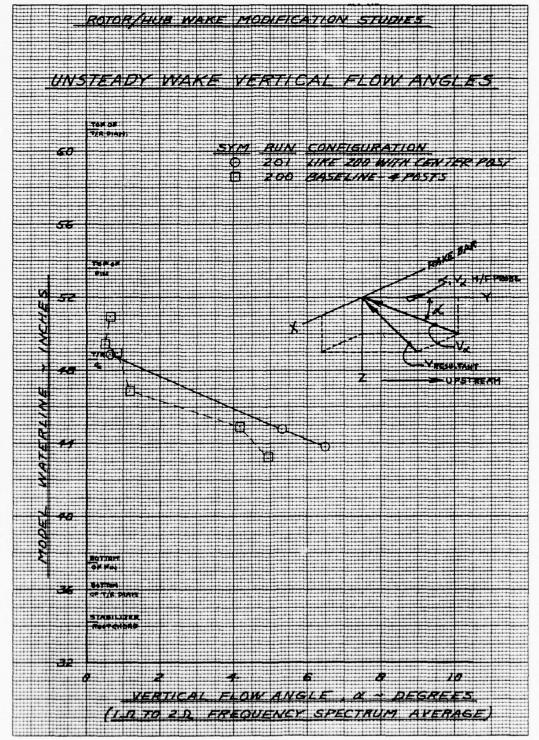


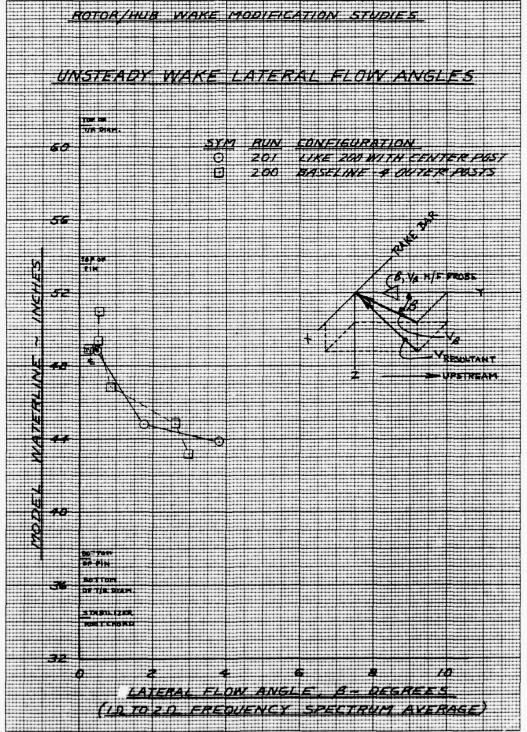


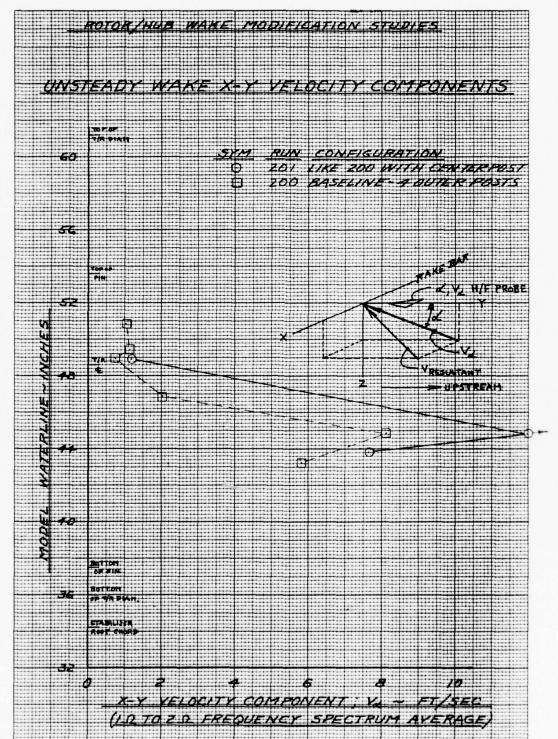


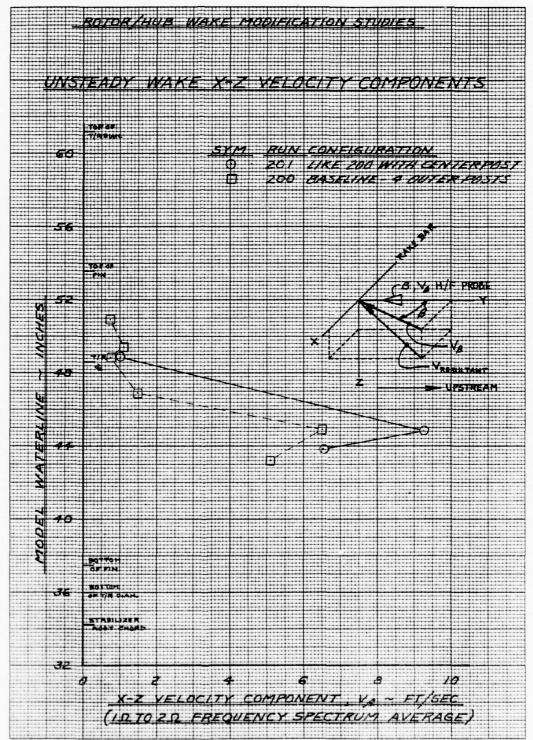


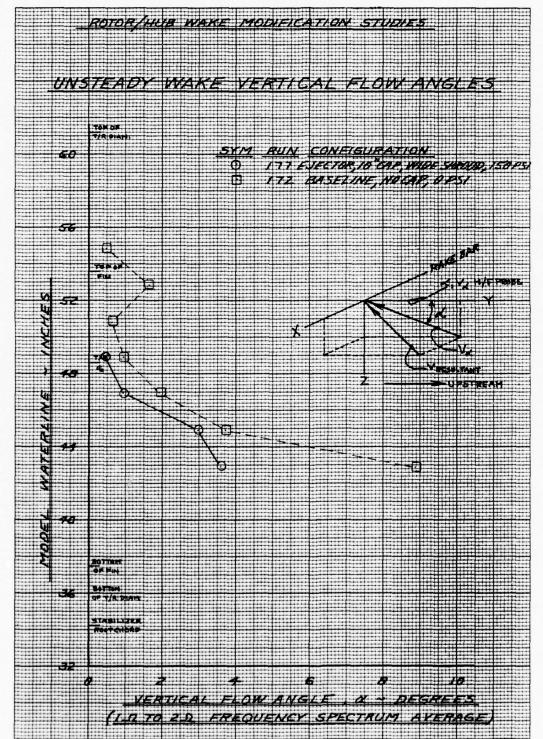


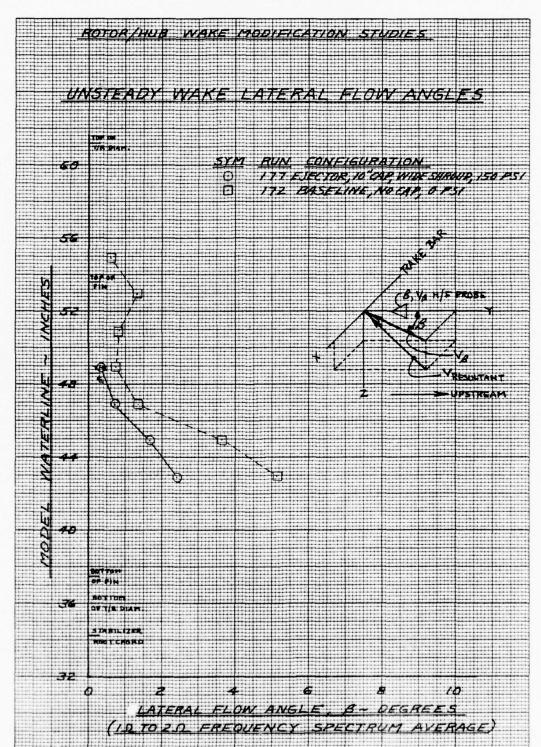


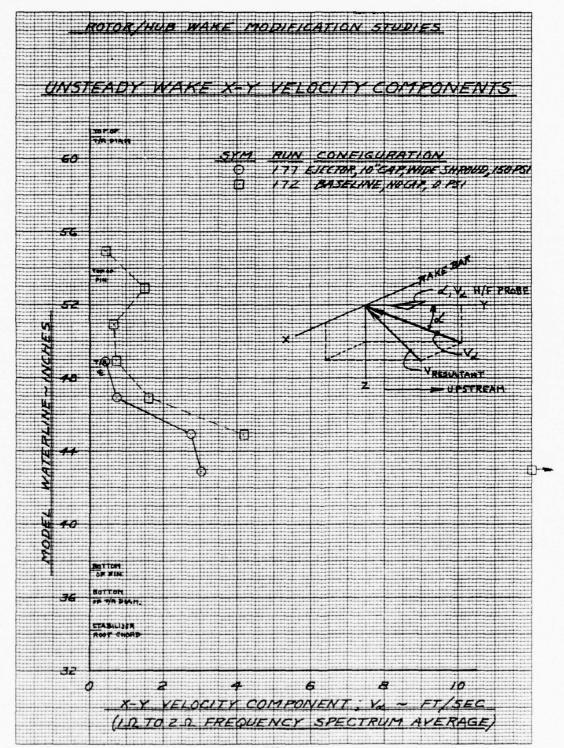


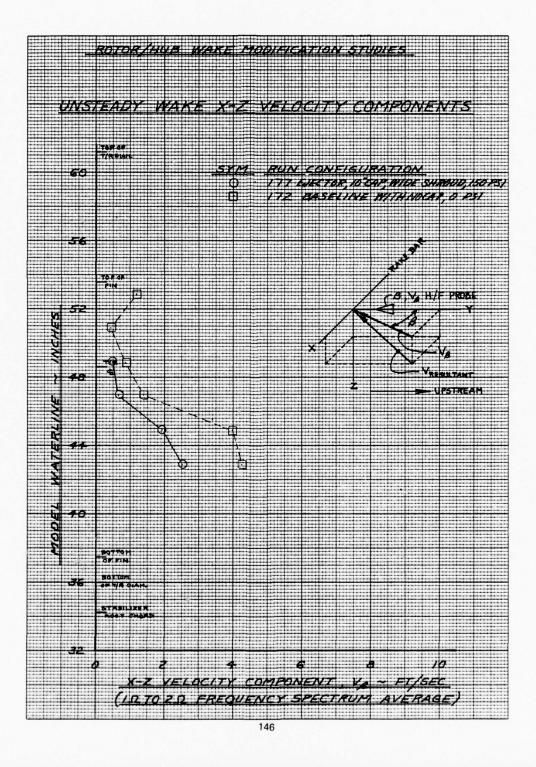


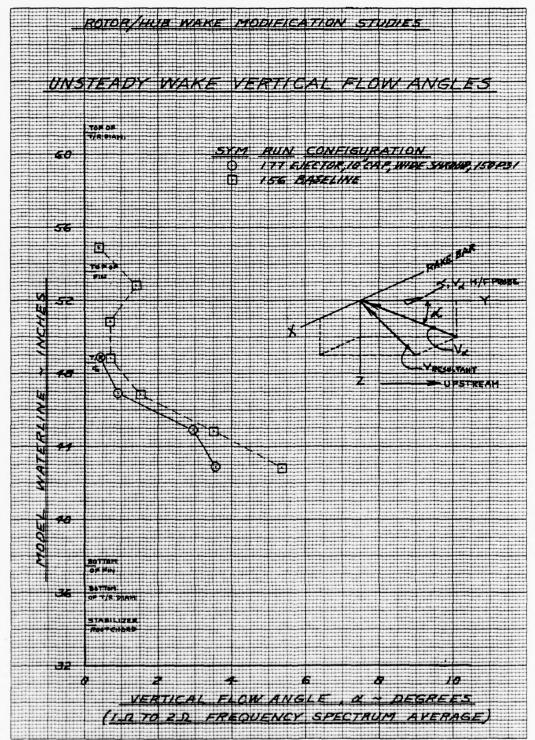


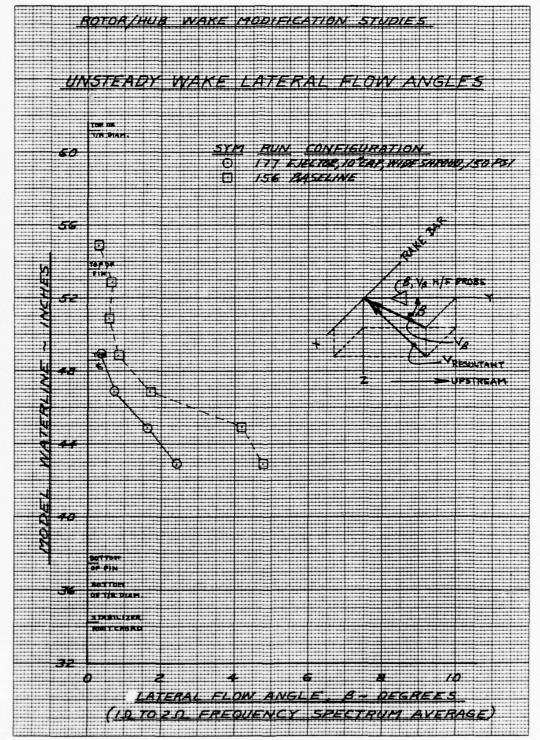


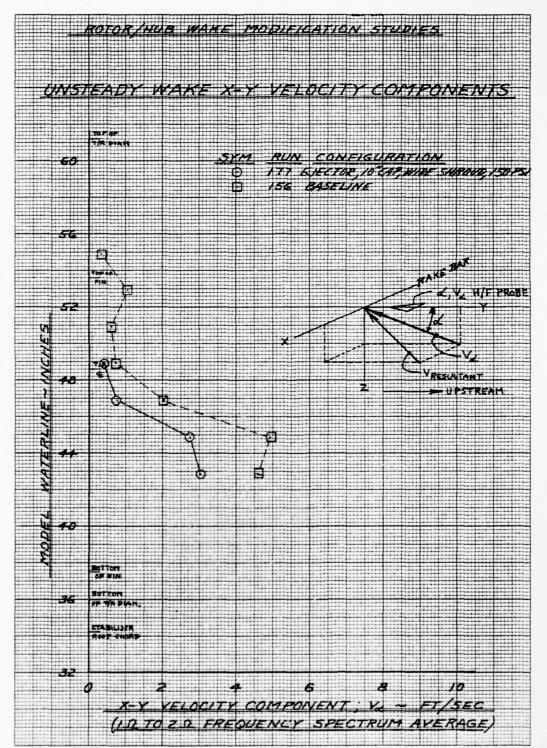


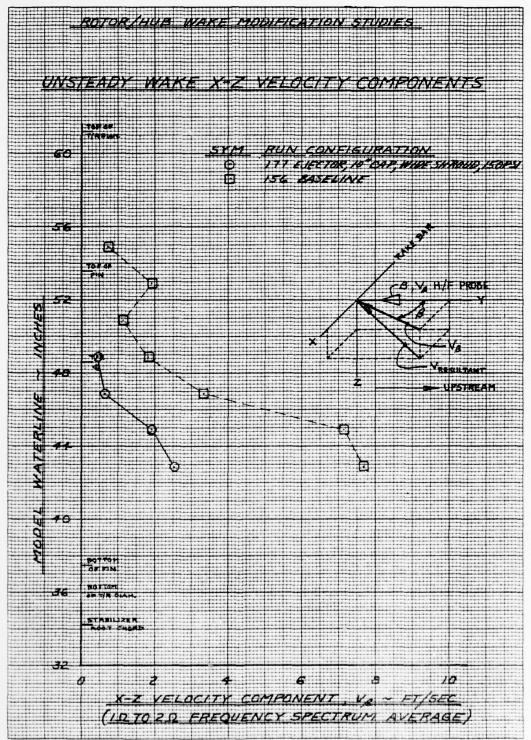


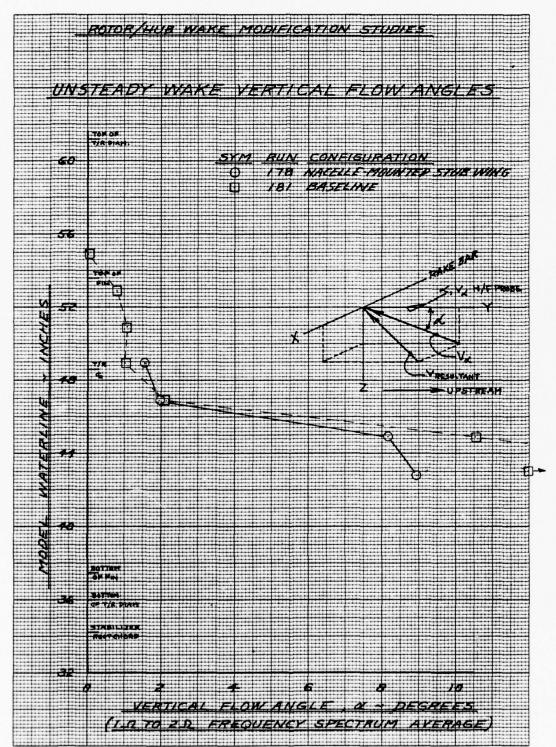


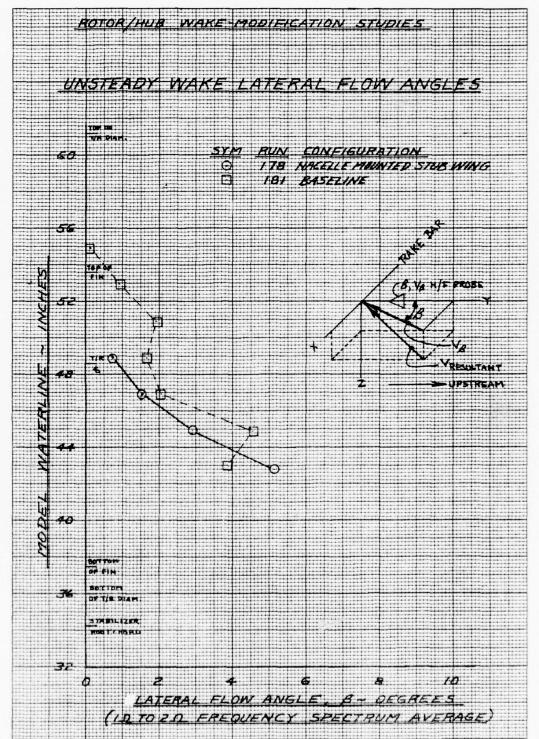


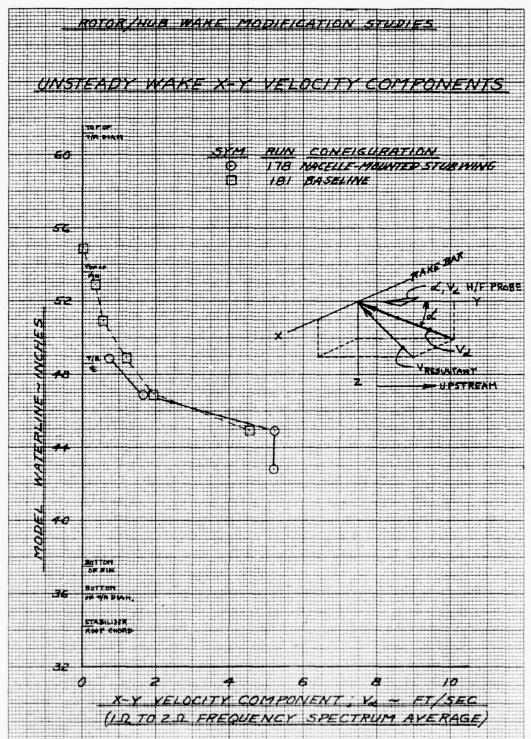


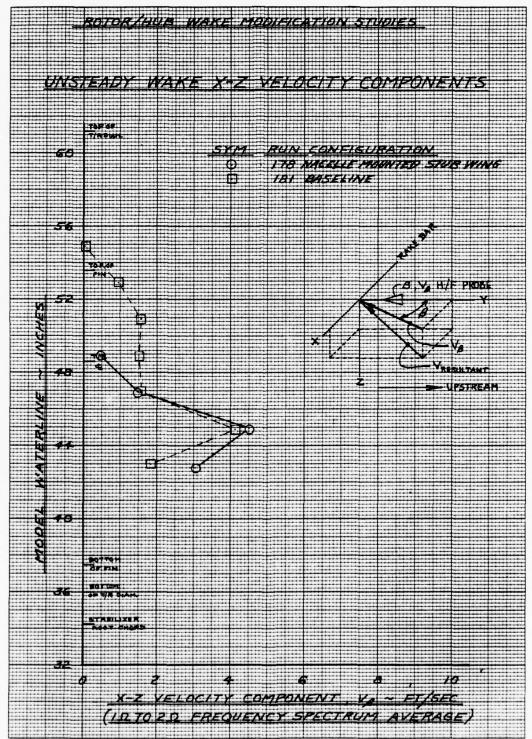


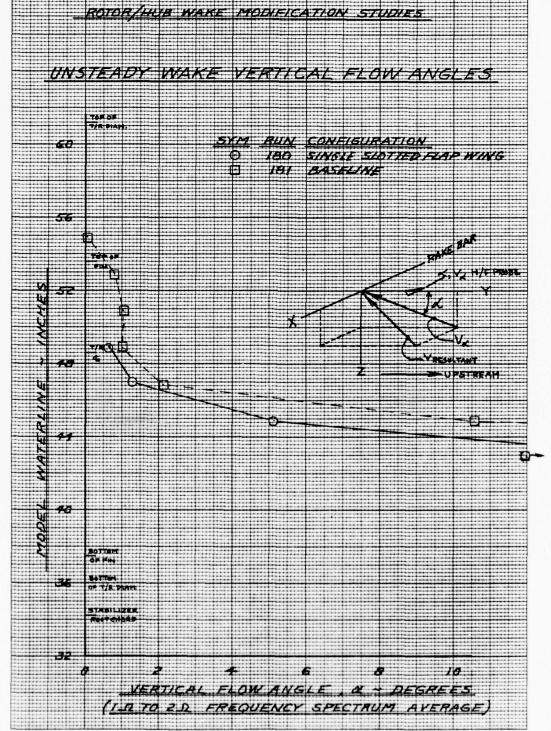


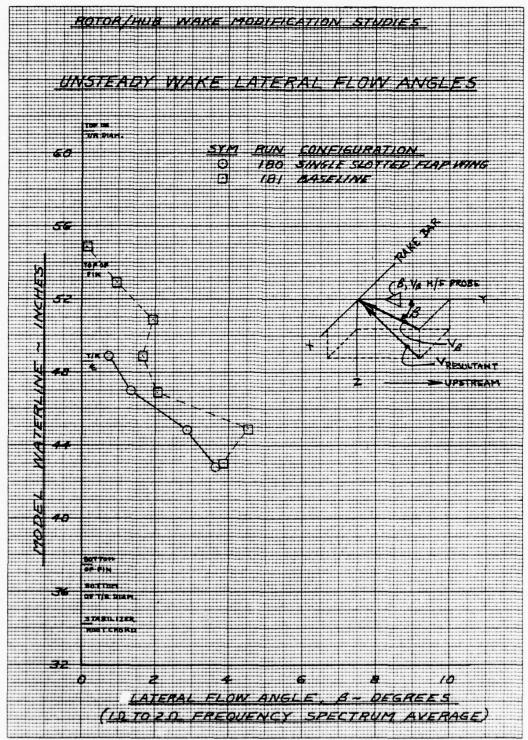


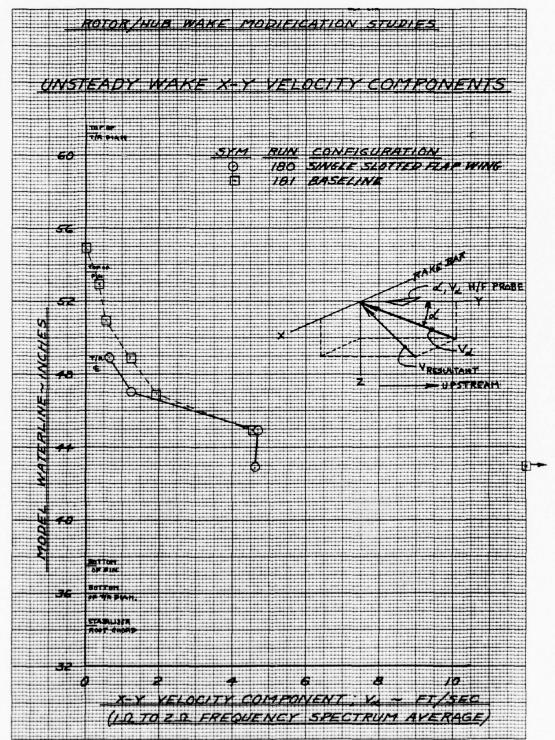


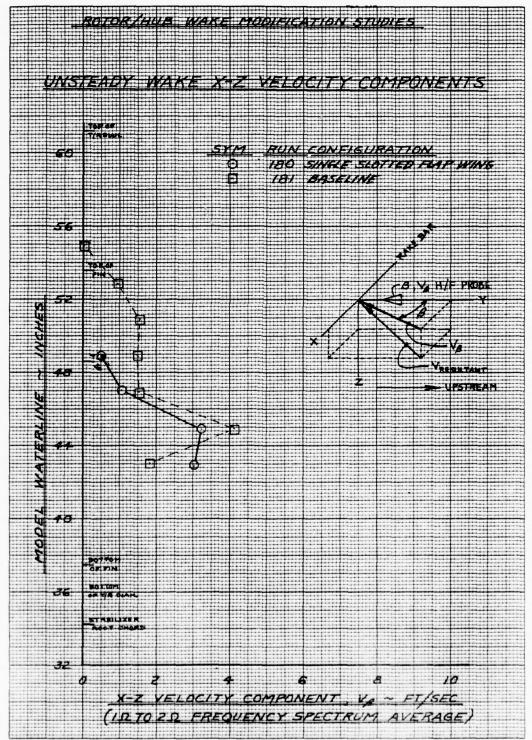


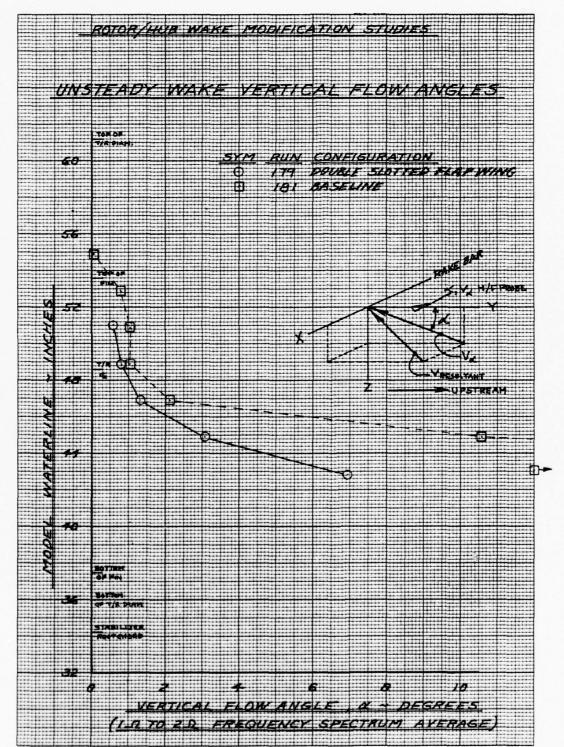


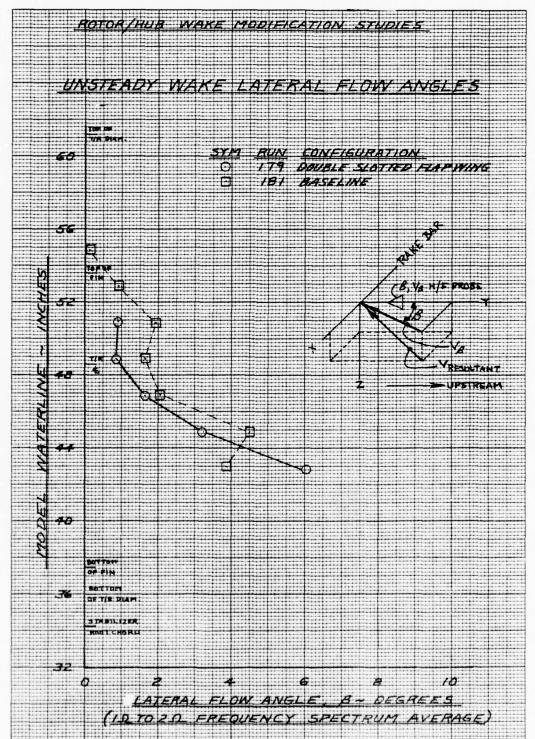


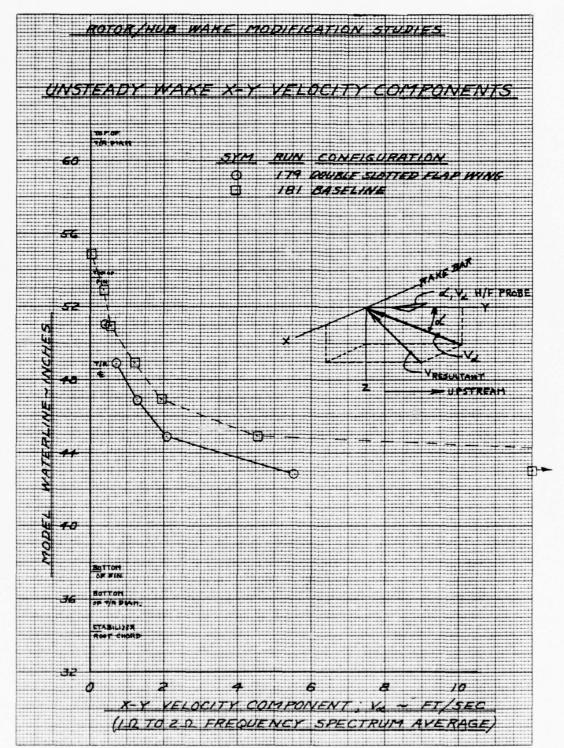


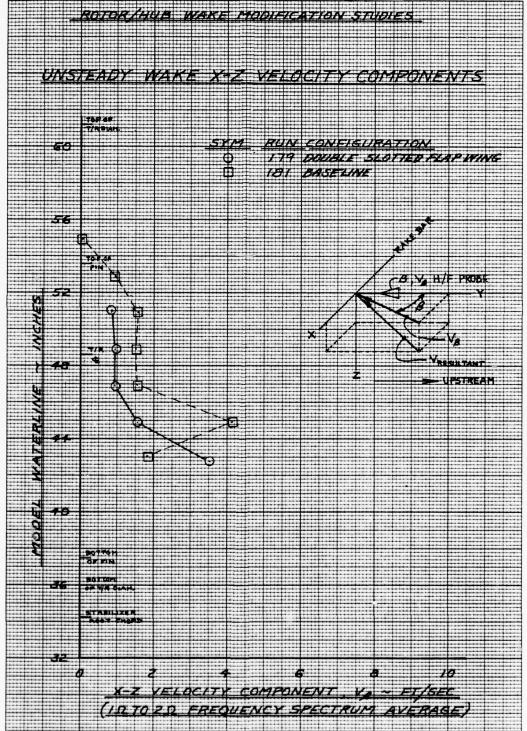


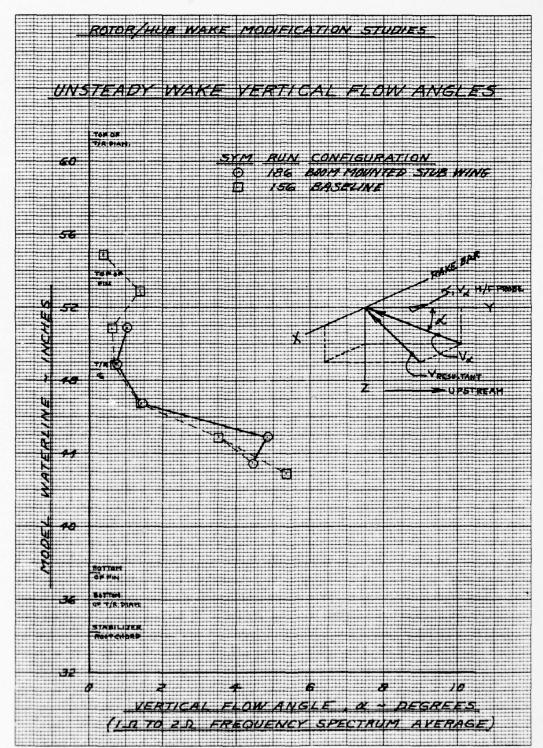


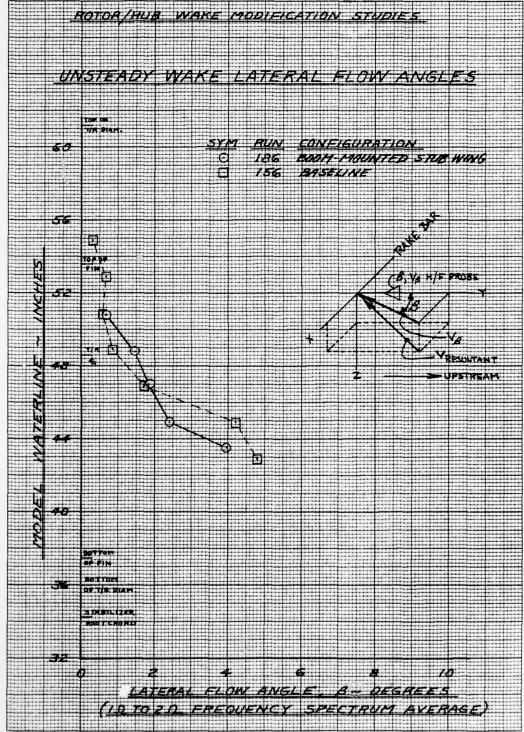


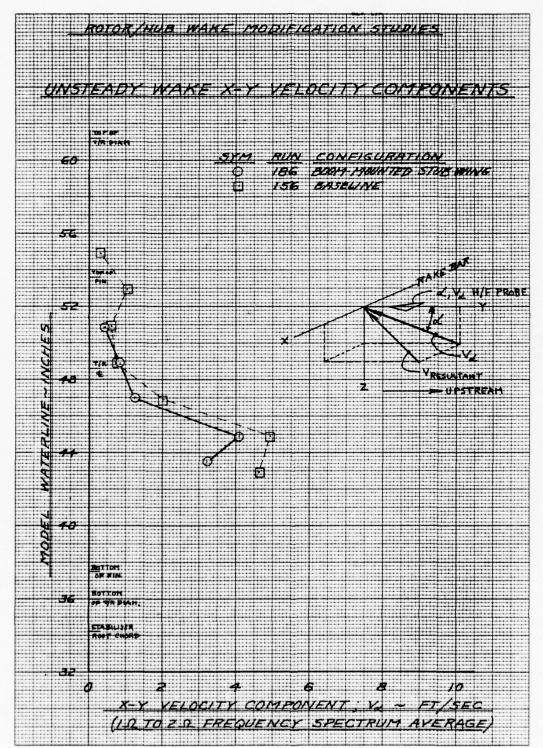


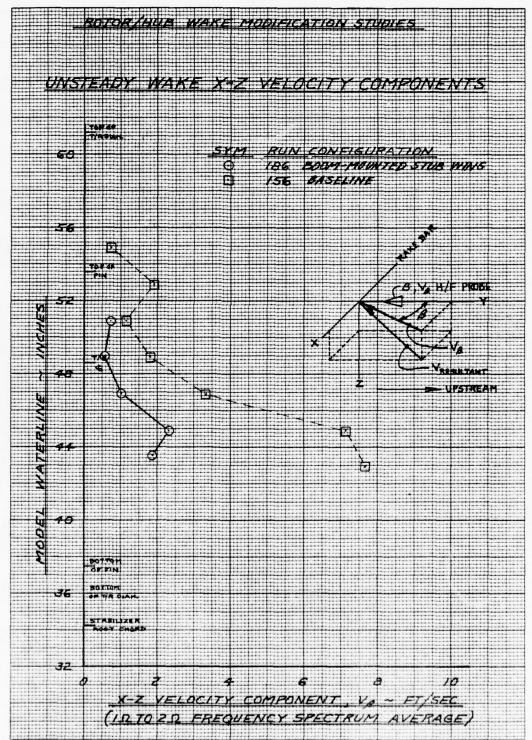


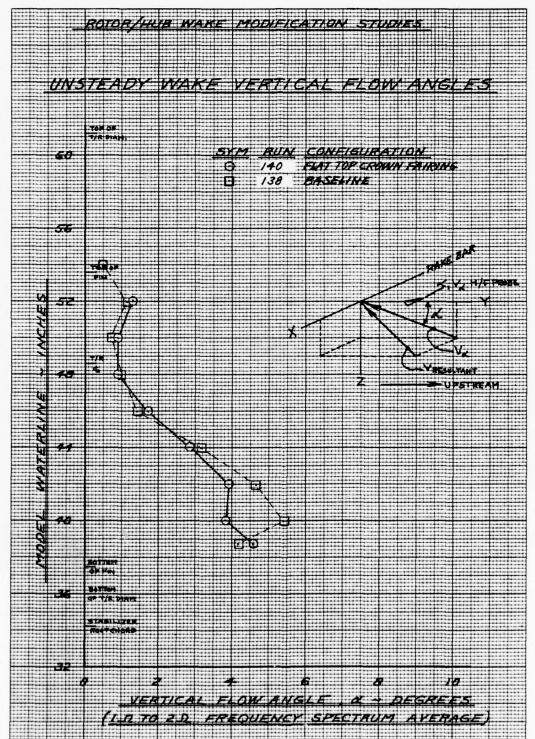


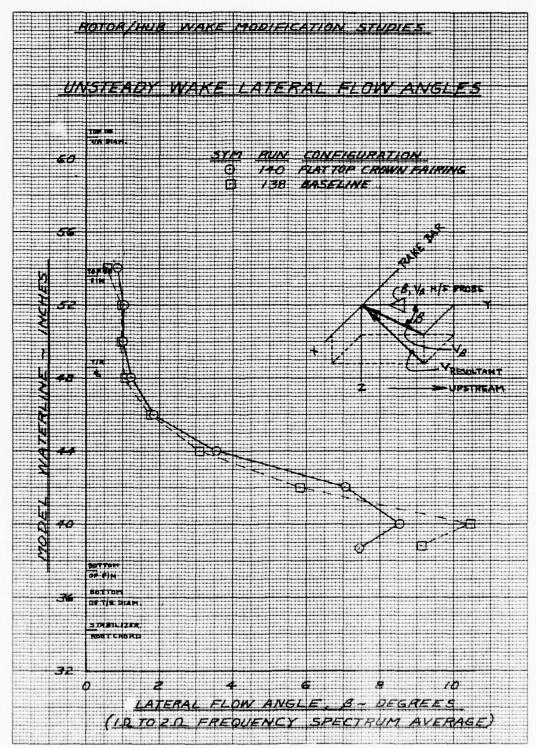


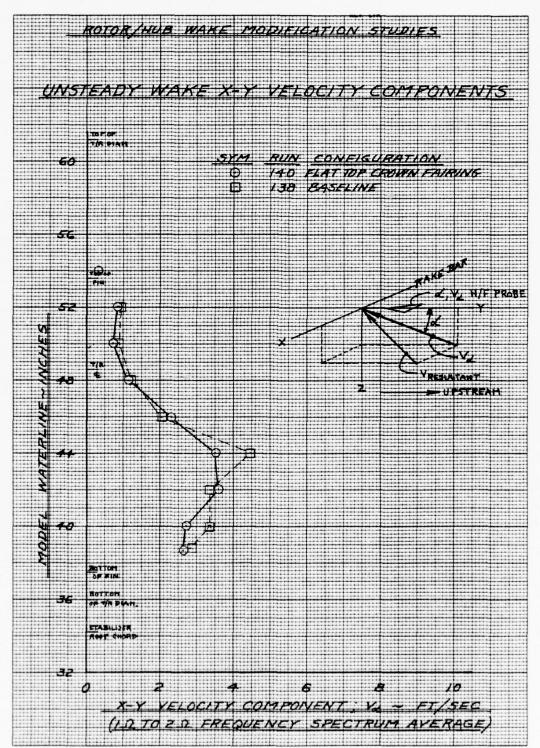


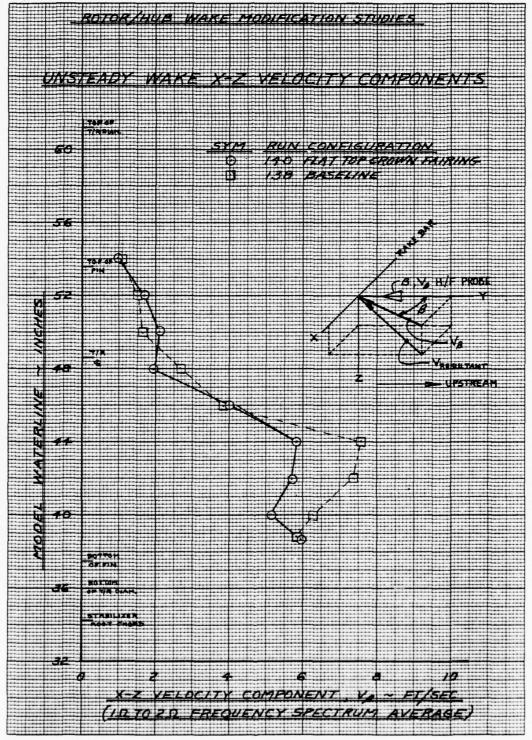


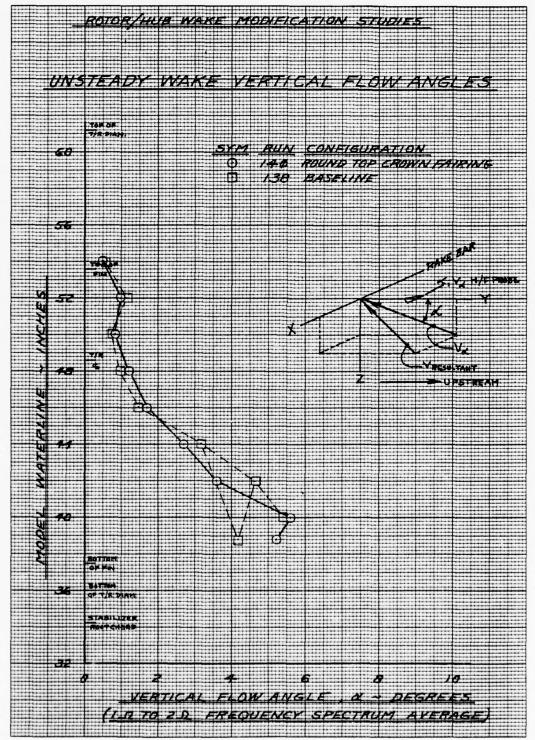


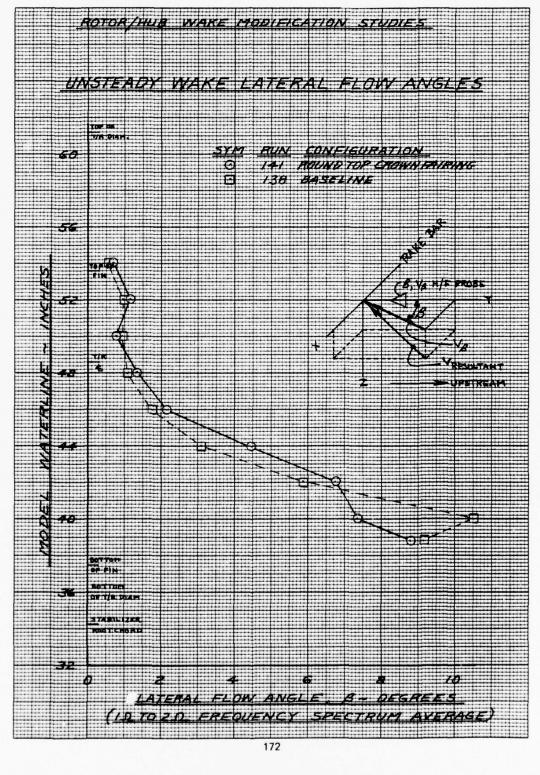


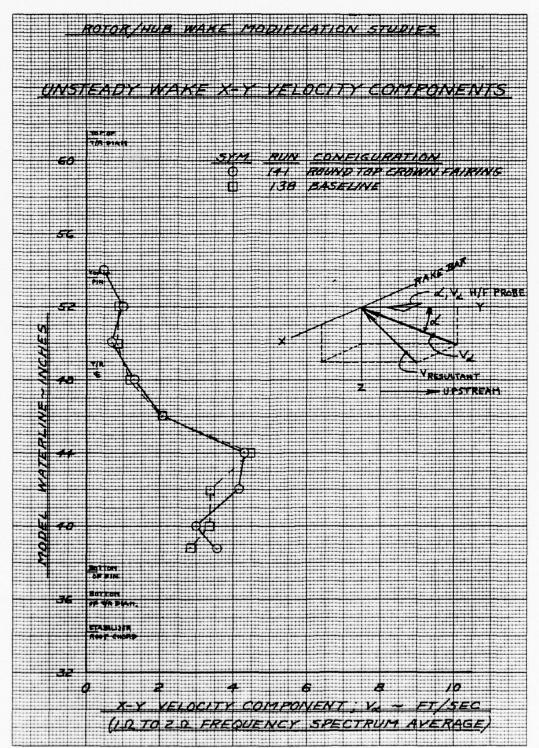


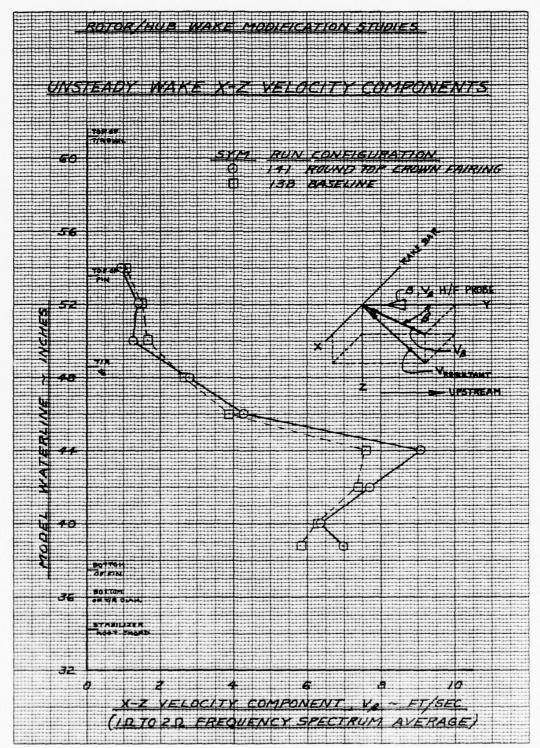


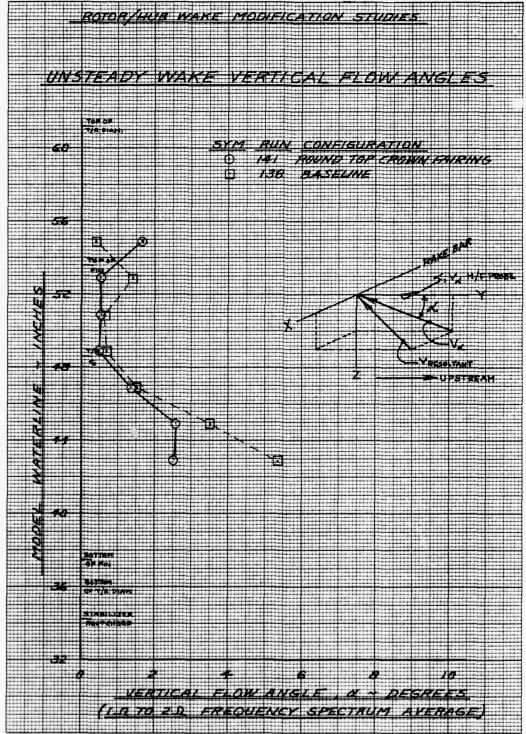


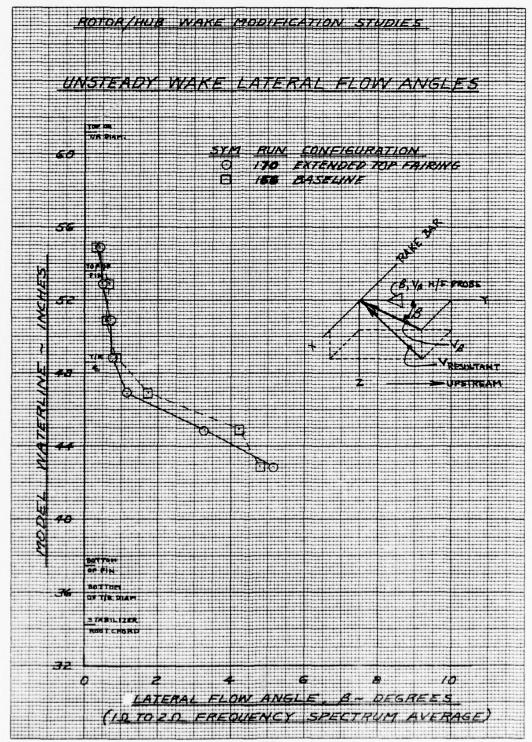


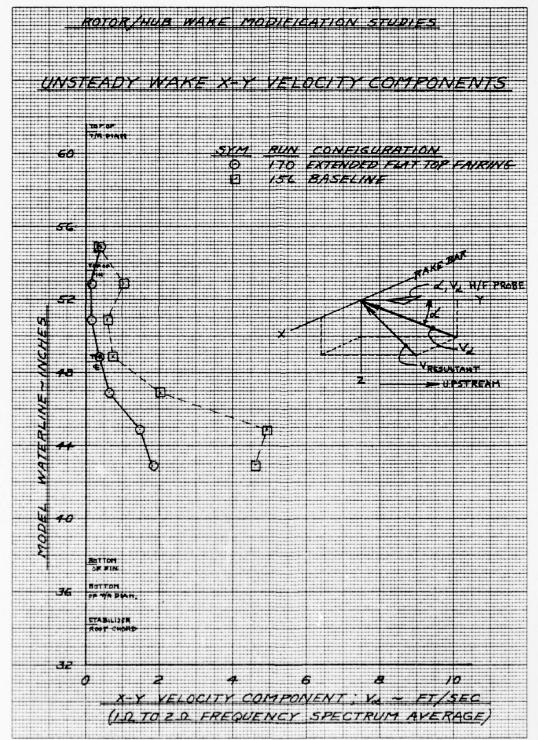


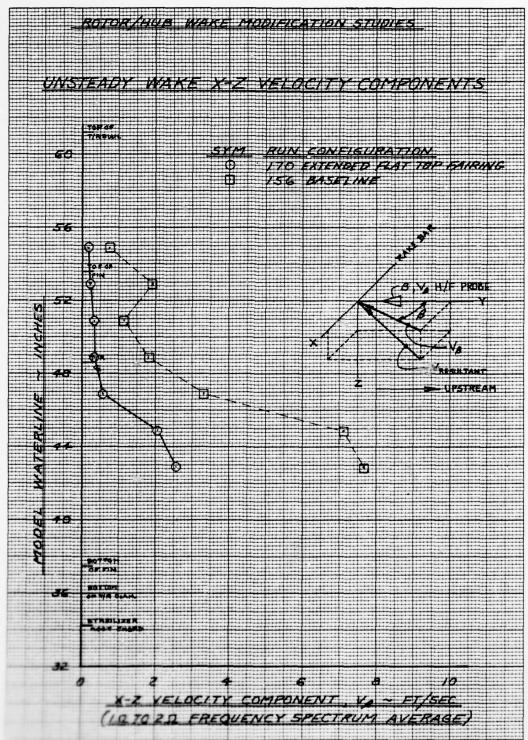


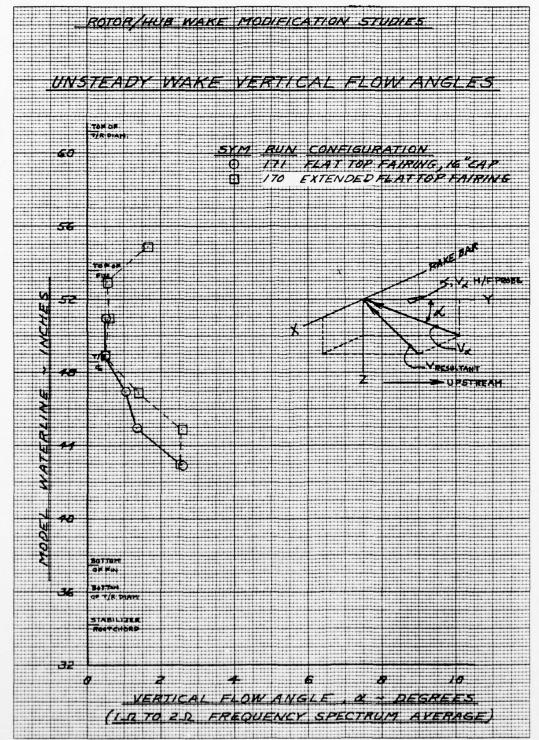


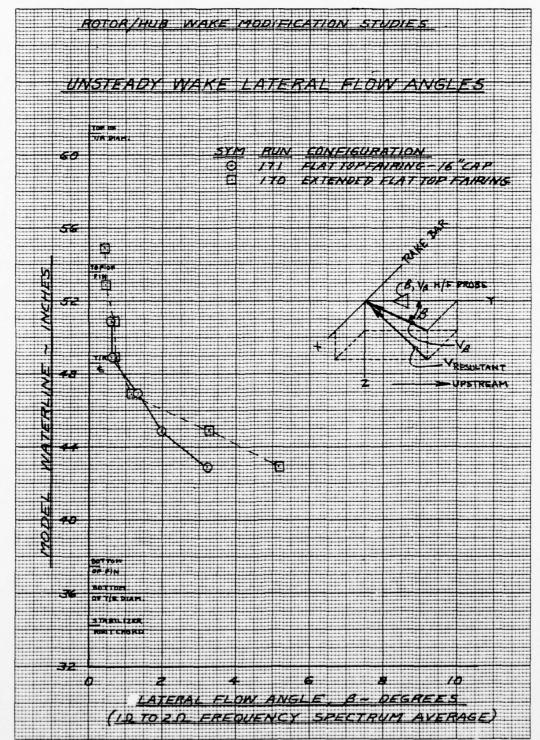


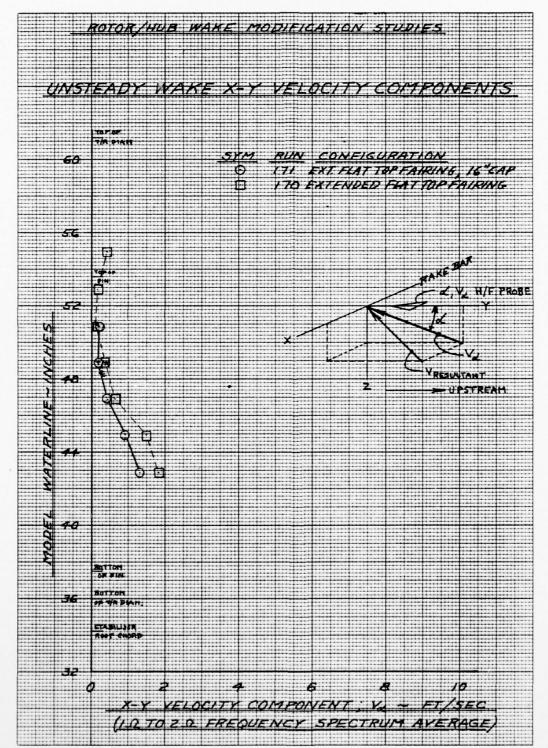


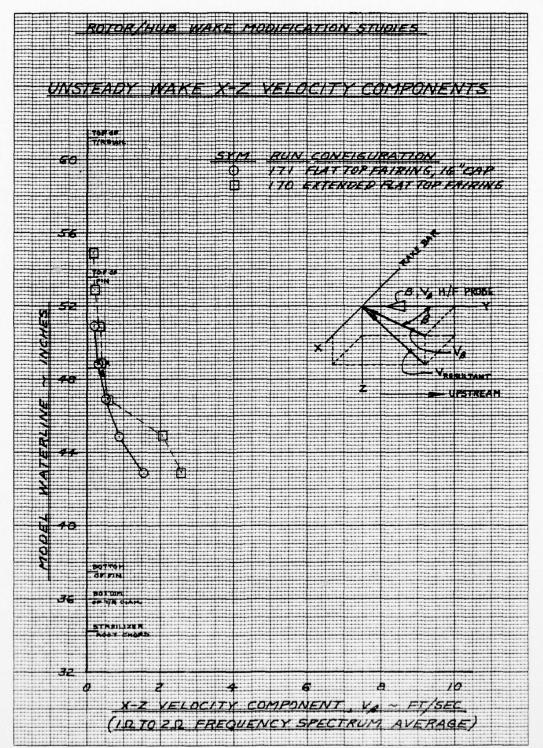


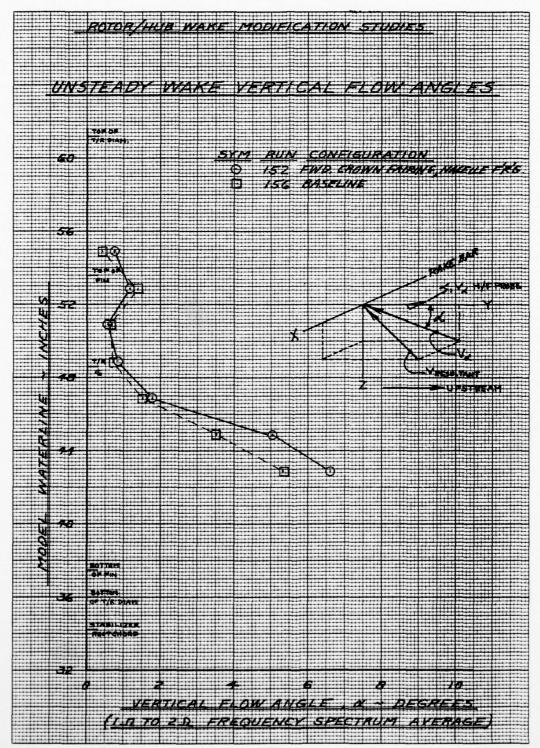


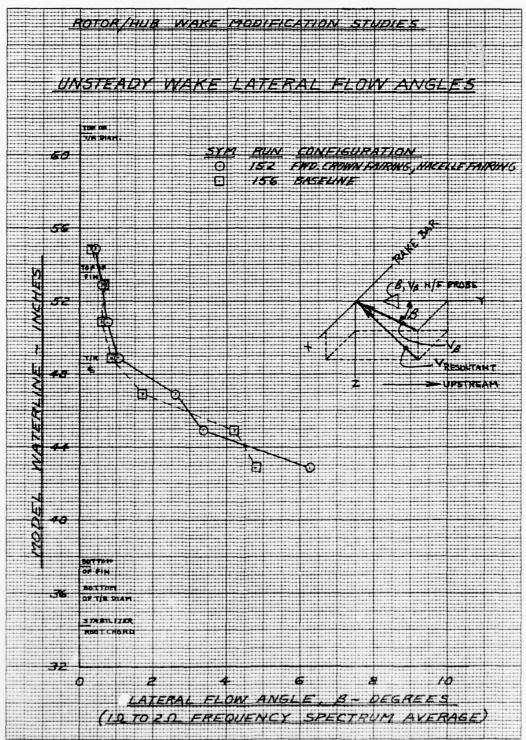


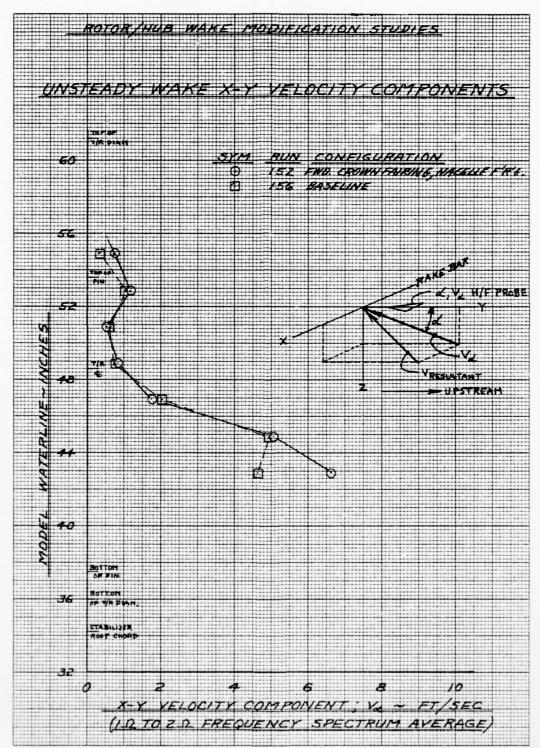


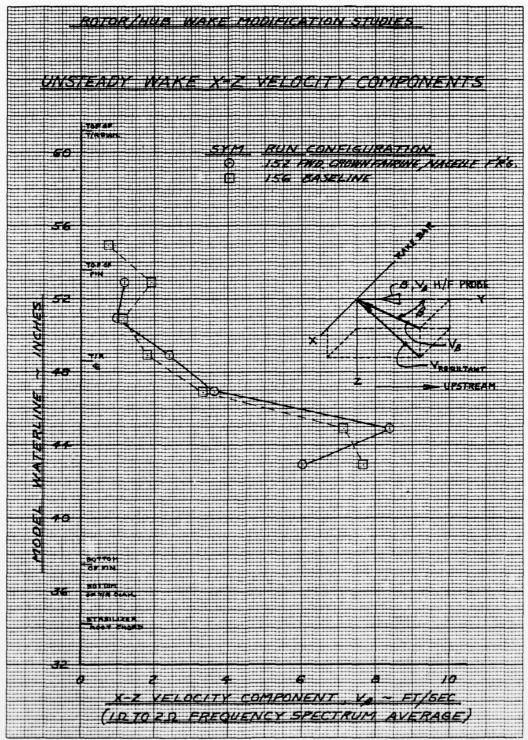


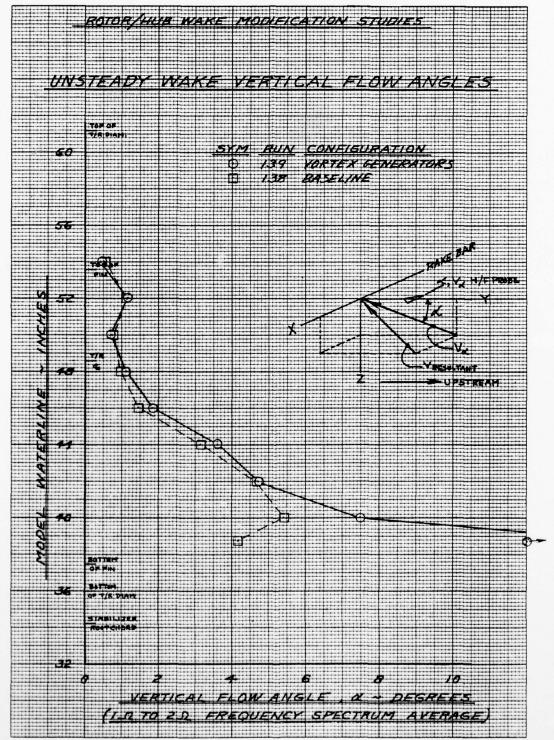


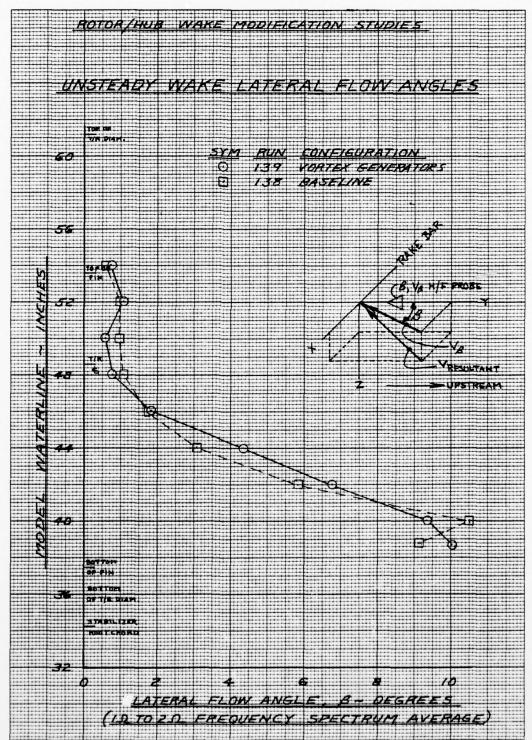


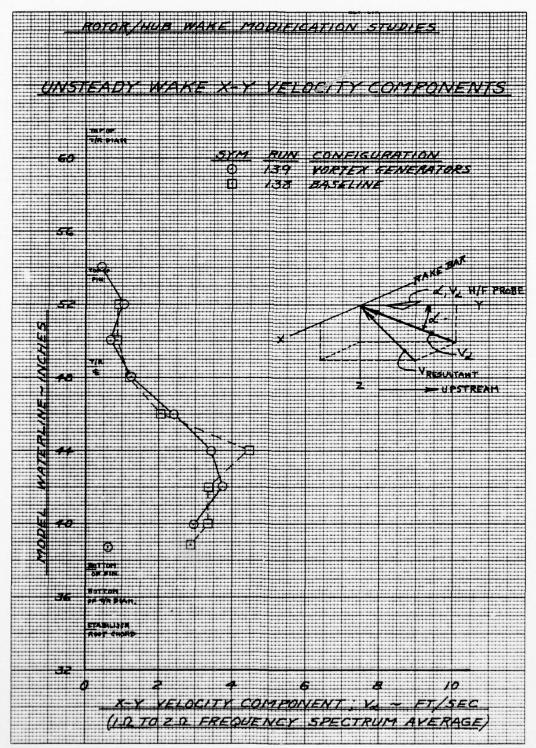


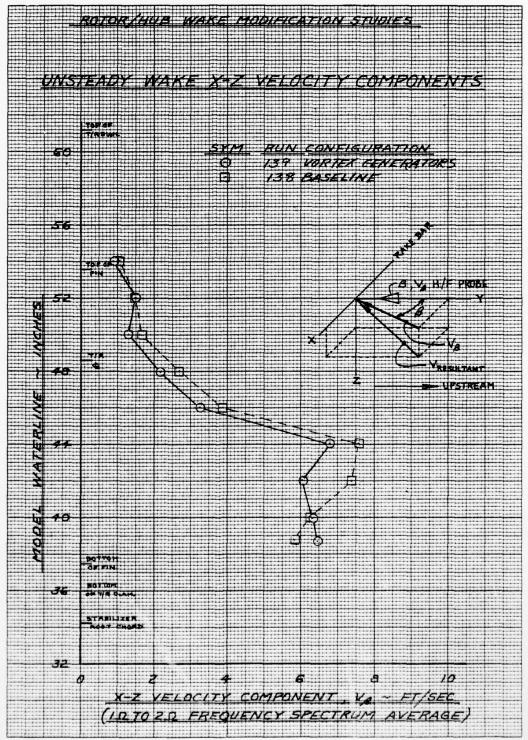


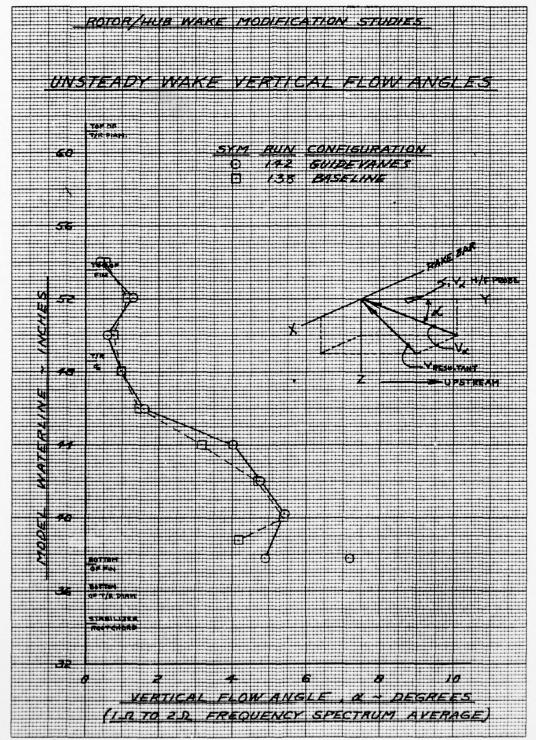












AD-A061 767

BOEING VERTOL CO PHILADELPHIA PA F/6 1/3
INTERACTIONAL AERODYNAMICS OF THE SINGLE ROTOR HELICOPTER CONFI--ETC(U)
SEP 78 P F SHERIDAN DAAJ02-77-C-0020
USARTL-TR-78-23C-VOL-3B NL

UNCLASSIFIED

3 OF 3 AD A061767























